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Russell

ON THE
ORGANIZATION OF SCIENTIFIC WORK
OF THE
GENERAL GOVERNMENT

BY

JOHN W. POWELL
DIRECTOR OF THE U. S. GEOLOGICAL SURVEY

Extracts from the testimony taken by the Joint Commission of the Senate and House of Representatives to "consider the present organizations of the Signal Service, Geological Survey, Coast and Geodetic Survey, and the Hydrographic Office of the Navy Department, with the view to secure greater efficiency and economy of administration."

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the latitude by astronomic methods, the longitude by connection with some known point by telegraphic methods. Having determined the position of the line on the face of the earth, its latitude, longitude, and its length, from such a line a system of triangulation is expanded. As we start from the base-line the triangles are comparatively small, but are steadily enlarged until their sides are from 40 to 50 miles in length. These triangles are grouped so that their sides form into quadrilaterals, so far as possible; sometimes into pentagons. By this means we obtain, scattered about the country, from 30 to 50 miles apart, fixed points. Within these we extend a secondary and tertiary system of triangles all over the country, and determine a vast number of points.

Question. When did your authority to execute this kind of work begin?

Answer. Three years ago; that is, the authority under which we are working now. For twelve or fifteen years anterior to the organization of the present Geological Survey there were several surveys which were prosecuting work of this character.

Q. Which were prosecuting geodetic work?

A. Yes, sir; in the sense here used; the work of the several parties is all indicated upon this map (indicating). The Wheeler work is this, the King work this, the Hayden work this, the Powell work this (indicating each time). Wheeler went over a very much larger area than is here shown, but the work was not of such a grade as to serve present purposes.

By Mr. HALE:

Q. This was all in the Western domain?

A. Yes, sir.

Q. None of it in the East?

A. No, sir.

Q. Will Major Powell give us his authority for extending the work in the old States; upon what authority does he prosecute that?

A. Have you the sundry civil bill of last year? [Receives the document from the clerk of the committee.] Here is the original act; the authority is this; it has been repeated from year to year.

By the CHAIRMAN:

Q. You do that under the provision for the geological map?

A. Yes, sir.

Q. This began when?

A. About three years ago.

Q. That would be about 1882?

A. Yes, sir; the wording is precisely the same in each act.

Q. Is the act you have in your hand the first or original one?

Mr. LYMAN. While he is looking that up I will call the attention of the chairman to the fact that Clarence King's first report, commenting on the act under which he was working at that time, stated that it was ambiguous, and went on to point out one or more places in which it was ambiguous, and especially he stated that it was not clear whether geological surveys were authorized to go into the States and do work there, though he was of opinion as an individual that they were so authorized, but he sought more light on that subject. This authority is evidently the outgrowth of that first doubt of Clarence King's, who preceded Major Powell.

Major POWELL. Three years ago—that would be in 1882, I think—the term "United States" was introduced into the bill by the House of Representatives, instead of the "national domain," after a long debate, for the purpose of extending these operations into the eastern part of the United States. Up to that time we had been doing a part of the work in the West which you see colored on the map. Three years ago, after a lengthy debate in the House, the operations of the surveys were extended to the eastern portion of the United States by changing the phraseology to "United States" instead of "national domain."

By Mr. HALE:

Q. That was the object of changing the phraseology?

A. Yes, sir; there was a difference of opinion as to what the term "national domain" meant, and it was averred that the term meant public domain. That opinion was accepted, so that the survey was not extended into the eastern portion of the United States until after the discussion in Congress to which I referred.

The CHAIRMAN. I notice in the appropriation bill for 1881 the words "national domain" are used; then, in 1882, the same words are used.

Major POWELL. But with an addition, I think, in 1882.

Mr. HALE. You mean in the bill for 1882?

The CHAIRMAN (reading): "Mineral resources and products of th national domain"; that is in the appropriation bill for the year endin June 30, 1882. Now, then, there is introduced into the bill for 188 the words "to continue the preparation of a geological map of the United States."

Mr. HALE. That is the first introduction?

Major POWELL. That is the first introduction of work into the eastern portion of the United States.

By Mr. HALE:

Q. You began the work before that?

A. No, sir.

Q. Did you not begin it in 1882?

A. I began it under the authority of that law. I will have to look back, or think back. This is 1885; the bill under which we are now working, as you designate bills, is for the fiscal year ending 1885. Thus designating by the last of the fiscal year instead of the first of the fiscal year, the act would be for the year 1883.

By the CHAIRMAN:

Q. You were entitled under this law to begin on the 1st of July, 1882?

A. Yes, sir; I began then and have been working three seasons, the present season being one, in the eastern portion of the United States. To return to the position of our base-lines in this area [indicating]—

The CHAIRMAN. Please describe it, so the reporter can give it i the record.

Major POWELL. There is one base-line for these portions of Maryland Virginia, West Virginia, Kentucky, Tennessee, Alabama, Georgia, North Carolina, and South Carolina. But the work does not rest solely on the base-line measured by the Geological Survey. It rests also on the triangulation in large part of the Coast and Geodetic Survey, which we utilize as far as it has been extended. Wherever the Coast and Geodetic Survey have done any work, we utilize it.

By the CHAIRMAN:

Q. You do not duplicate that work?

A. No, sir.

Q. That is to say, where work has been done by the Coast and Geodetic Survey, you send for their maps; or how do you proceed?

A. We send for their determination of points. We do that frequently. We send requesting the determination of certain points which they have, and they respond promptly as a rule. We also utilize the points of the lake survey and of the State surveys, such as New York, Massachusetts, &c.

Q. You utilize everything?

A. We utilize everything that we can.

Q. Then you do not survey where you find surveys have already been made?

A. No, sir.

Q. Do you verify these surveys?

A. Yes, sir.

Q. Or do you take it for granted they are correct?

A. We see that they are correct by checks that are afforded through connecting lines with work done by ourselves.

Q. Look at that map again and state what the different colorings represent with reference to your work.

A. Commencing in Texas, this colored margin shows the topography and triangulation of the Coast Survey. That also extends, as you see, into Maryland and still north to Maine.

Q. That means what the Coast Survey has done?

A. Yes, sir.

Q. Not what you have done?

A. No, sir; I have put the work of every organization on this map.

Q. I see a long line running up into the interior there.

Q. That is the triangulation of the Coast Survey on the Mississippi River.

Q. How far is that extended?

A. Not more than 200 miles. This [indicating] is the work of the United States Engineers on the Mississippi River.

Q. What is the color of that line?

A. Blue, or a very bluish tint.

The CHAIRMAN. I am endeavoring to have you so state that the stenographer can put it on paper.

Major POWELL. Very well. Then this [indicating], the sepia color, represents the triangulation and topography of the Coast and Geodetic Survey. In addition to that, the Coast and Geodetic Survey has done some work of triangulation where it has done no topography. That is represented by another method; that is, by cross-bars and the sepia, as shown here [indicating]. That is the work of the Coast and Geodetic Survey; their triangulation without topography. This triangulation without color, simply plain cross-bars, is the triangulation of the State of New York across that State.

By the CHAIRMAN:

Q. Made under State authority?

A. Made under State authority. The triangulation here [indicating], without color, but with simple cross-bars, in Massachusetts, is the Borden triangulation of the commonwealth. The topography and triangulation of the shores of the lakes, colored deep blue, is the work of the Army Engineers in their survey of the lakes. The triangulation across here [indicating], in detached area marked by the cross-bars and blue color, represents the Engineer's triangulation without topography.

Q. That is across the peninsula of Michigan and down into Indiana, which is the triangulation by the Engineers?

A. Yes, sir. It was conducted under the organization for the survey of the Great Lakes. The large areas colored in blocks represent the triangulation and topography completed by the Geological Survey and the antecedent surveys of Wheeler, Hayden, King, and Powell. The State of Massachusetts, at the last session of its legislature, made an appropriation of $40,000 for a topographic survey of the State of Massachusetts. That work is put under my charge. The scale on which I was making the map of the United States did not satisfy the scientific men of Massachusetts; they wanted a larger scale than we had adopted, and wanted the work done on a scale which I thought was not warranted by the appropriation which had been made by Congress. After asking me to do this more elaborate work, which would be of certain value in determining the water-supply of cities and towns, and in various other ways, I was authorized to make a map of the State. I did not think I had authority to make it as desired by their local officers. The State of Massachusetts thereupon made the appropriation of $40,000 and put that work under the Geological Survey in order that we should enlarge the work to a scale suited to their purposes. I had the year before commenced the work on our own plan, and the change was made to suit Massachusetts.

Mr. Lyman. What scale will that be?

Major Powell. 1-62500. My general work in the East is 2 miles to the inch. The four areas colored blue in the map represent the four areas in Massachusetts covered by the joint work of Massachusetts and the Geological Survey. The green is in like manner, and under somewhat similar circumstances, the joint work of the State of New Jersey and the United States Geological Survey.

The Chairman. They having made——

Major Powell. A similar provision.

By the Chairman:

Q. How much have they appropriated for the work?

A. They have not appropriated fully for the work. They have appropriated only for one year—for the experimental work of one year.

By Mr. Hale:

Q. Under what kind of authority do you, the head of the Geological Survey, do the work for the State; under a State appropriation?

A. The State appoints a commission which officially controls the work. The Director of the Geological Survey directs the conduct of the work.

Q. Under what authority do you do that?

A. Only the authority that comes from the request of that State commission.

Q. How can you embody that into your work; a State matter, is it not, clearly? Where do you get the authority for it?

A. I have no other authority but that I was carrying on a survey in the State of Massachusetts and the State proposed to do one half of that work while I did the other half, and at the same time they permit me to direct all the work in Massachusetts. The commission is composed of General Walker, Professor Shaler, and a gentleman of the Coast Survey, Mr. Whiting.

Q. Do you call that a State or a national survey?

A. We call it a national survey. They turn over the control of the work to the national survey.

The CHAIRMAN. Let me ask you a question. That scale you speak of contemplates a map of two miles to the square inch?

Mr. LYMAN. One square mile to a longitudinal inch?

The CHAIRMAN. That is better. That scale contemplates two miles to the longitudinal inch?

Major POWELL. Yes, sir.

By the CHAIRMAN:

This map will be one mile to the longitudinal inch; is that all the difference?

A. That is it.

Q. Is it not practicable to enlarge these maps? Suppose you made a map under the United States such as you made for other States, could not the authorities of Massachusetts have enlarged that map?

A. Yes, sir; but with the enlargement of the scale goes the determination of additional particulars on the ground.

Q. Oh, you enlarge the scale in the beginning so as to put more things on your map?

A. Yes, sir.

Q. Can you not get all these things on a map representing two miles to he inch?

A. That is a question which goes to the foundation of this subject of opography. There are two classes of things to be represented on a map. The natural features, such as the rivers, and all the drainage, the mountains, the hills, &c. In the second place, the artificial features, the railroads, the roads, the towns, the quarries, and things of that kind. Now, in the construction of maps, a certain amount of cost must be charged to the natural topography. A certain other amount of cost to the cultural topography, as it is technically called.

Mr. LYMAN. By "culture" I know what you mean; it sounds like agriculture, and you mean——

Major POWELL. Everything which can be represented on the map which is the work of man. Now, in the representation of the cultural features or artificial features upon the map consists a large part of the cost. In the United States we put upon the map less of this culture than they do in Europe, because the maps in Europe are made on the theory that they may be used for battle maps, and hence they include all fences, all vineyards, all orchards, all ditches, all quarries, all wells, &c. Now, in the United States we do not construct maps for this purpose and in this manner, and the cost of the additional work of this character as done in Europe is very great.

By the CHAIRMAN:

Q. I see. Do you regard that as a valuable thing to do?

A. Only certain parts of it. I am informed that the British Government has within the past year appointed what they call a Commission of Exclusion, on the theory that they have heretofore put too much of that culture upon their maps, and as they speedily become obsolete they must be reproduced very often. For the last ten years I have been defending the plan which contemplates the delineation of only those eatures of very substantial nature, such as relates to canals, towns, oads, &c.

Q. Now, will you just tell us what you do put or will put upon these maps when disconnected with the partnerships with the States?

A. In the first place we put upon the map the drainage, every stream with its meanders; second, we put upon the map outlines of every marsh, lake, and other body of water; in the third place, we put upon it every hill, every elevation of any kind, hill or mountain, and in such a manner by contour lines that not only is the relation of one part to another given, but the relation of each to the level of the sea, so that you may take the map and lay out upon it a canal or conduit; for example, should you wish to bring the water of the Potomac to Washington, you could lay out the general route of that canal upon such a map; or, wishing to lay out a country road among the hills, you could do the same, and wishing to lay out a railroad you could do the same. That is, the map is published with grade curves, the contour lines representing the relative altitude of the parts and absolute altitude from the level of the sea. In addition we put upon the map exclusively for the United States, all railroads, all canals, all highways, &c., but use some discrimination in the selection or exclusion of certain unimportant or minor roads, especially where not established by law. We put upon the map all towns, but do not put farm-houses; we do not put private roads upon the map; we do not put stone quarries upon that map, and many other things which are put upon the maps in Europe.

Q. Who designs this map as to what should be placed upon it? That is, who designates the things that should go upon this map?

A. It is done practically by officials—it is done by myself practically. But I have held consultations with the geographers and topographers of the Survey. The matter has been discussed for years and the practice grown up by experience.

Q. The Secretary of the Interior exercises no authority in reference to it?

A. No, sir; except that I report to him and he approves. He does not take any initial act in the matter.

Q. Has any section of this map been completed?

A. It has.

Q. Have you a copy of the completed portion?

A. Yes; I have some sheets here.

Q. I mean completed of the work in the States.

A. No part of the work in the States has been engraved. These are of the Territories. These are specimens. May I telephone for others?

[The major directs his clerk to telephone for Mr. Bodfish's maps.]

Q. Have you described, Major Powell, everything that you put on this map?

A. No, sir.

Q. I want to get a description of everything that you include in this map?

A. I cannot state that fully without an examination at the office.

Q. You mean every material thing?

A. I have not described every important thing; there are certain mineral interests and important mining districts put upon the map; but they do not extend everywhere. Something depends upon the peculiar section of the country as to what secondary things will be represented. In certain districts in the West, for instance, ruins will be shown. In the Valley of the Mississippi we include groups of great mounds, &c., and many little particulars of that kind, now in this district, now in that district.

Q. Local things?

A. Yes; when I get the proof-sheets of the maps I will explain it fully.

Q. I want now to ask you what you understand by a geological map.

A. I only have to describe the practice of constructing geologic maps for the last fifty years, not only in the United States, but all over the world. A geologic map has, in the first place for its basis, geography or topography, such as I have described. In the second place, the geologic formations, which are composed in part of sheets of rock, and which are displaced and contorted and eroded away in various places, and represent different geologic ages—all these are outlined in colors on the chart. In order to make the geologic map we trace out the areas occupied by the several geologic formations. In mapping they have been careful to follow the contour of the hills and valleys. Formations do not run in straight lines because of their inclination or dip, and for other causes; they outcrop irregularly in the hills and valleys and mountains. The geologic structure of the country is examined by the geologist with map in hand, and as he goes over the hills and across the valleys, he places the colors on the map to show the geologic formations which come to the surface, some coming to the surface from below and others being spread over the surface. Now, in addition to that, on the margin of the map or on an accompanying sheet are constructed diagrams or sections like the profile of a railroad. These diagrams or sections are constructed and accompany the map to fully interpret it.

Q. In other words, it is necessary to have a topographical map before you can make a geological map?

A. Yes, sir; it is fundamentally necessary for a geologic map; and for that reason many States have initiated topographic operations in connection with geologic surveys.

Q. Is it necessary that this topographical map should be absolutely accurate in order to designate on it the geological formation and structure of the section?

A. Every error appearing in the geographic part or topographic part of a map projects itself into the geology and vitiates the geologic representation to that extent.

By Mr. HALE:

Q. If you have errors in the topographical map. every error is propagated?

A. Yes, sir.

Q. To make what is known as a geological map you must make, preparatory to that, a complete topographical map?

A. Yes, sir.

Q. Let me go a little further. Have not many, and perhaps most, of the States, at different times, had geological surveys heretofore?

A. Several have.

Q. Have they been based upon previously made and completed topographical surveys or without them?

A. Some have; others not.

Q. In most cases have they not been made without topographical surveys, upon which the geological map is dependent?

A. Well, I will have to separate the question into parts.

Q. Let me illustrate. Take Massachusetts. Massachusetts has had geological surveys; Maine has had geological surveys; Pennsylvania has had geological surveys. Have any of these States, in order to present to their people the geology of the State, gone on and prepared for it by previous topographic surveys?

A. Maine and Massachusetts properly never had a geologic survey. Pennsylvania has, and Pennsylvania makes topographic maps. Maine has had an examination of certain rocks of the State for the purpose of discovering whether there were ores in her rocks. Massachusetts, I believe, has not even gone so far as that, but Massachusetts commenced many years ago at the very basis to make a topographic survey, and Massachusetts has turned over to the Geological Survey all of that preliminary work, which I mentioned awhile ago as the Borden triangulation. Pennsylvania, for example, has a geologic survey, but it is now being based upon a topographic survey.

Q. Have they been construed as being in any way connected? For instance, the authority for a geological map as granted by provision in an appropriation bill. Do you suppose that that carried in Congress, or elsewhere, any expectation of your going on and making triangulation, topographic work, and a complete topographic map of the United States? Do you suppose anybody construed it that way, or expected that?

A. If the Senator will read the debate upon this matter in the House of Representatives in times past, he will find the passage of it hinged upon that point; and it was elaborately and fully discussed, and was adopted with that understanding. It was thus discussed, and all our western work for the twelve years preceding the organization of the Geological Survey had progressed on that theory. In Pennsylvania, in New Hampshire, in New Jersey, in Virginia, in Michigan, and elsewhere, the geologic surveys carried on topographic surveys. In New York the geologic survey has never to the present time constructed such maps. Maine has never constructed such maps. A number of the States have topographic surveys but have not attempted to construct a geologic map. Usually it is only in those States where they have attempted to construct geologic maps that something has been done in topography—sometimes more, sometimes less, as in Pennsylvania. In California, for example, the first year's work was put on topography, the survey carried on by Professor Whitney, in which Clarence King was engaged anterior to his doing this work for the Government. The survey of King, and that of Powell, as well as the other geologic surveys, were all based on topography; so that it has been the practice in the States and the practice under the General Government alike, in the preparation of a geologic map, to make a topographic map as its basis.

Q. I want to ask one more question here. I am well aware that these States have to some extent made topographic surveys. Where they have made those surveys are they made under the designation of geological surveys or topographical surveys?

A. The practice has been diverse. In Virginia, Pennsylvania, North Carolina, California, and Michigan, for example, the topographic surveys were considered as accessory parts of the geologic survey.

Q. They are termed topographic surveys?

A. No, sir; geological surveys. In Massachusetts they started some years ago, perhaps about forty years ago, a purely topographic survey.

Mr. LYMAN. Senator Hale asked you a question, and I think it is an important one—is a topographic survey a necessary predecessor of a geological map? Now, for my own part, I cannot conceive of a geological map which is not preceded with a topographic survey of the utmost accuracy, and I would like to ask Major Powell's opinion on that.

Major POWELL. A proper geologic map cannot be made without the basis of a topographic map.

Mr. HERBERT. Let me ask you right there: In a State like Alabama that has the public land system and in which all the sections have been laid off, and the lands marked, could you not take that as a basis? Whether those surveys are correct or incorrect it is according to the surveys upon which the lands have been sold and parceled out, and could you not take that survey as a basis, and, practically, would it not be just as good as a perfect and complete map?

The CHAIRMAN. You mean as a basis of the topographical survey?

Mr. HERBERT. No; take that as the topographic map itself. What you want to know is the section where the minerals are contained principally, more than to locate them, with reference to the lands actually laid off by Government surveys, whether correct or incorrect.

By the CHAIRMAN:

Q. If lands are marked and known, could not the geology be described with reference to those lands as a basis, and would it not practically be just as valuable? I mean a geologic map constructed on that basis.

A. It would be possible to make a geologic map of a district of country which had been previously surveyed by the township system of the United States, and write a report of those observations stating that certain facts were discovered, say, on the northeast quarter of the southeast quarter of a certain section, and go on in that way and make a report based upon it in that manner, and the map of such a district compiled from township plats into a general map could be made, but with very much less accuracy than it could be made the other way, for the reason that the township maps do not give complete facts of topography. The Land Office maps do not give the complete drainage, nor do they give the hills and the valleys, nor do they give the roads of the country or any part of the culture, so far as that is concerned. But if I may go on a little further and explain that those township maps are yet not fully lost to our work, for we take those township maps with the notes of the field surveyors on file in the General Land Office, plat them together on large sheets, but on a smaller scale, take them into the field and put the additional material upon the sheets, and use them for our purpose, so that those preliminary maps of the Land Office will be of some use to us, though very little compared with their cost. We have made an experiment in this matter.

Q. Where is that?

A. That is partly in Kansas, partly in Missouri, and partly in Arkansas.

Mr. LYMAN. Major, perhaps you will let me read your own words for us again. It is in a report that touches this very point. I think it will save some time if I read it [reading]:

> These records of the Land Office furnish a gigantic illustration of the evils of badly-directed scientific work. A large corps of surveyors has been employed for nearly a century. Forests, prairies, plains, and mountains have been traversed in many directions; millions of miles have been run with compass and chain; chart after chart has been constructed with great labor; folio on folio has been placed among the national archives containing facts incoherent and worthless; and the record has been made that here are trees, there swamps, and yonder glades; that the lands surveyed are level, hilly, or rolling; that sandstones are found here, limestones there, or granite elsewhere; and so the records of useless facts have been piled up from year to year until they are buried in their own mass. That all of this labor and expense has been lost to science may well challenge the attention of the learned men of America, and when properly understood they will not be slow in demanding a reform.

By Mr. HERBERT:

Q. Suppose that all information of that kind were left out, and that a geological survey located as accurately as possible the sections in which coal was to be found, or iron and other minerals, and other kinds of rocks, what would be the necessity of locating roads and hills accurately?

A. The geologic report based upon such a map would be of value, but of very little value.

Q. Would it be of small practical value for you to locate the sections where these different things are for a complete topographic map?

A. It would be of very little practical value, because we could not outline the formations. We do not usually tell a man, "You can go and find a mine on such a fraction of a section," but make outlines of the geologic formations in which ores are found, and every man exploits his own land. If we were to make an exploitation of each plotted section, we might say what was found on each section. But the Geological Survey does not attempt that. It does a thing which is very much less expensive. It simply outlines formations where coal is found, for example. We simply map the district of country by showing where the formations crop out on the hills and across the valleys. These formations may stand nearly vertical, or at high angles, or with low dips warped and twisted, and hence a map is necessary showing the hills and valleys. If I were at my office I could show you geologic models and make this very plain.

By the CHAIRMAN:

Q. I want to see if I understand this business now. I am getting a little confused. You speak now of a topographic and of a geographical map, and of a geological map. I think we have had those three terms used.

A. Yes, sir.

Q. I used the term "topographic map," and you said you thought it ought more properly be called a geographical map. Now, suppose a map was made by the Land Office, based on their surveys, what sort of a map would that be? Would that be a geographical map?

A. No, sir. It would properly be neither a geographic nor a topographic map in the sense in which those terms have been used by me.

Q. These maps made under the General Land Office would be simply, then, a land map?

A. Yes, sir. Let me suppose they have marked out a district of country into sections and other divisions of land. They have not determined the latitude and longitude of any point; they can plot that district by itself, but not in its relation to other districts, and they might guess at the longitude and latitude and be five, ten, or twenty miles in error with reference to the true position.

Q. Now that is just what I am coming at. They have surveyed the lands and fixed the latitudes and longitudes, and base lines and range lines, have they not?

A. They have fixed the base and range lines on the ground.

Q. Now, are these accurate or inaccurate?

A. Let me show you what the land survey does.

Q. Answer me first. Are these accurate or inaccurate, with reference to the things that they deal with, of course?

A. Yes, sir; reasonably so.

Q. With reference to the things they deal with they are reasonably accurate?

A. I can take a sheet of paper in my office and plot upon it the thirty-six sections of a township, according to the scale I may adopt. This is a chart of thirty-six sections, and made without going into the field or measuring the land. Then I may go into the field and measure a township of thirty-six sections and mark it with section stakes. The chart which I made in the office before measuring the land is a proper chart of the township, but not a proper map. It does not show the streams, the hills, the valleys, or any of the natural features of the land, and is as good a map of any other township in the world as of the particular township which I have surveyed.

Q. I understand that. I will ask you another question, so that you will see what I am trying to get at. You take the State of Alabama, which has been surveyed under the land system, and General Herbert has bought a section of land which is described in his title-deed. That of course is based on the survey already made. Now, you make a new survey covering topography, the geography, and base lines, &c., and you find that the land which his deed calls for is not the land which he occupies, but land 20 rods from it or 30 rods from it. Is not that possible under your system?

A. No, sir; we never attempt to fix the artificial boundaries which are established to mark landed properties.

Q. But you fix latitude and longitude. Suppose you fix it half a mile or a quarter of a mile from where it is fixed by the land maps?

A. It has no effect whatever on land-office work. The land surveys are not based on the meridians and parallels recognized by geographers. They go into the country and lay out parcels of land and put stakes down to mark boundary lines, and the titles rest upon those stakes, wherever they may be, and however erroneously they may have been placed.

Q. Suppose the stakes are lost; suppose I have land upon the fifth meridian——

A. But nobody can tell where that meridian is, except by coming upon the stakes. The sense in which the terms parallel and meridian are used in the Land Office is altogether different from the sense in which they are used by geographers. They are there used to designate certain lines upon the ground. Geographers use those terms to designate lines at certain distances from established points, like the capital of a country, or Greenwich.

Q. Do you mean to say that when a meridian is described in the Land Office that it has nothing to do with the natural meridian?

A. It would be the natural meridian of a point accidentally or arbitrarily selected by the Land Office; but giving it a name and a number does not fix its relation to the meridians used by geographers east and west from Greenwich; for example, the first meridian started from a point where the first stake was driven, and the only way of finding that point is to find the stake. The second meridian was the second starting point, marked at an accidental point by the driving of a stake. The distance from the first meridian to the second meridian could only be known by subsequent measurement, and no actual or theoretic distance was assumed. The practice of numbering meridians has practically been abandoned, and most of the meridians now used by the Land Office take their name from some object at or near the initial point from which the line starts. The initial meridian of the geographer runs through the observatory at Greenwich; for example, the first meridian west runs sixty minutes west of that, and it may or may not be marked on the ground at any place; the second meridian runs two degrees west, and so on. The first meridian established by the Land Office was where they happened to drive the first stake; the second meridian where they happened to drive the second starting stake; the distance between the two meridians was never considered. Land Office meridians and geographic meridians are two very different things.

By Mr. HALE:

Q. Take the line of a State which, as embodied in a statute law of the adjoining commonwealth, is declared to run upon such a meridian; that, you say, has nothing to do with the meridians as fixed by the scientific world?

A. That is an entirely different question. If in the statute you fix a boundary of a Territory by geographic co-ordinates, that is by latitude and longitude, such boundary is to be determined by such methods as geographers use.

Q. Now, suppose that I have the lines of a State as fixed by a survey of the General Government, and tracts of land have been bought bounded upon such a meridian and lying upon such a meridian, then would not that survey control in fixing the Land Office surveys?

A. The State line may be established on a meridian as designated by geographers; the public lands may be based upon a meridian as designated by the Land Office; but they would have no pre-determined relation to each other. The Land Office meridian might be 25 feet or 25,000 feet, or any other distance from the geographic meridian, and a man's 40-acre tract of land might lie on both sides of the State line. A strip 25 feet in width might lie in one State and all the rest in the other State. The boundary line in each State being a designated meridian from an established point would in no way control the meridian upon which the land title is based.

Q. But those lands are surveyed from the fixed boundaries of the State, are they not?

A. Land-title lines have nothing to do with State lines when State lines are established on meridians and lands are described by land-office methods.

Q. Let me ask you this question: In those regions of the West which have been surveyed scientifically under your superintendence, and in which the lines have been going on contemporaneously with your surveys, are they in any manner related to each other—the surveys by the Land Office and your surveys? Have they any bearing on each other?

A. No, sir.

Q. So that your survey does not help the land surveys to be more accurate there?

A. No, sir; not at all.

Q. No relation between the two?

A. No, sir; except that we take their township plats and utilize them to such an extent as we can in constructing maps.

Mr. HALE. It is not any argument in favor of or against your survey, or any of these other surveys, that the land surveys have to be made also, because they are entirely independent of each other.

Major POWELL. They are entirely independent of each other so far as marking out parcels of ground are concerned.

By the CHAIRMAN:

Q. That is to say, your map and your survey has no relation whatever to the lines and boundaries of land?

A. No, sir.

Q. And will not effect the old surveys or the surveys to be made hereafter?

A. No, sir; but this is done by the geographic surveys. Suppose the Land Office starts here on the Niobrara River to make township surveys, and calls the line running north and south through the point which it accidently selects the Niobrara meridian (or may be the 10th meridian if they happened to have nine meridians already), and goes on and surveys a large district of country, running lines from this Niobrara meridian. After that work is all done and the geographic surveys proper are extended over the same territory it may be determined that the Niobrara meridian was in longitude 78° 7′ 13″ west of Greenwich. Having thus determined it we know where to plat it upon the map, and if there chance to be a road running along that line we would put it down upon that map, but that would have no effect whatever upon land titles. They rest upon the Land Office meridians that are marked upon the ground.

Q. But providing that the Niobrara meridian has been scientifically made before?

A. The latitude and longitude of the starting points in the land surveys are never scientifically established.

Q. But does not a man commencing those surveys have to fix the latitude and longitude before he begins?

A. No, sir.

Q. The surveyor goes to the line and sets a stake and makes surveys from that stake?

A. Yes, sir.

Q. Is that the way when the meridians have been established? Have they not stated this as the first, or the second, or the third principal meridian?

A. Yes, sir.

Q. Suppose that meridian is not where they said it was?

A. Oh, they only say the meridian is where they have driven the stake; the term "meridian" used in a land title does not mean the same thing as the term "meridian" used in speaking of longitude.

Q. Now, I am going to repeat my question. I want you to tell me, suppose I have a section of land in Iowa, and it is described as relating to a certain meridian, certain lines, parallels, &c., as our deeds are described; suppose every vestige of those stakes is swept away, and I want you to make a survey, handing you my title deeds, and you make the survey from my deed, fixing the meridian and fixing the location; now where will it be?

A. It would not be anywhere as discovered by a geographic survey, if it depended upon geographic surveying for its discovery. If all the marks on the ground were lost the original lines could not be discovered.

Q. That is to say, when you take these land surveys without having the visible stakes it is impossible to tell where they are located?

A. Perfectly impossible. There is no possible way if the marks upon the ground are lost.

By Mr. HALE:

Q. But if Congress fixes the line it is different?

A. Yes; if Congress fixes, for example, a State line in terms of longitude.

Q. Now, suppose the title is to land on surveys which are made by authority of an act of Congress, just as a State line is fixed by an act of Congress. You say an entirely different rule applies there; but with a State line so fixed the State has the basis of an act of Congress. Do you think the courts would maintain that difference?

A. They always do.

Mr. HALE. That is news to me.

Major POWELL. In Bloomington, Ill., the meridian on which the land titles of that city were based passed through the city. The stakes were lost upon the ground, and the bounds could not be determined. The value of that property was great. It ended in litigation, and they had to correct uncertainity of titles by going to the legislature and securing the appointment of a commission under the court to settle the equities of the matter by establishing a line.

By the CHAIRMAN:

Q. Re-established the old line?

A. They could not find the old line. When the new line was established the property holders on that line had, under the decision of the commission, to exchange deeds or titles with each other to the several parcels allotted to them by the State commission. Land Office meridians are lines which run north and south, and there may be a vast, indefinite number of meridians. You might start a line north and south from every point on the equator of the earth—each one would be a meridian. A man may drive a stake in the ground anywhere and measure off a line north and south from that stake, and that line is on a meridian. He may describe that meridian and say it is the meridian of my stake, and if you wish to know where that meridian is you must find the stake. But geographers take some established point, and, by the late International Convention in Washington, that point is probably hereafter to be Greenwich, and we have in the United States to a large extent used that as the initial point in longitude; and geographers in using meridians in map-making speak of "meridian" in relation to that point, Greenwich, and not to some stake which by chance may be set upon the face of the earth. The boundaries of all lands in the United States the title of which comes from the United States and which have been surveyed under the general land system, relate not to the initial point at the Observatory in Washington or to any one single predetermined point, but they relate to different points or meridians; one parcel of land to an accidental starting point here, another parcel to an accidental starting point there; and so these starting points have been mutiplied over the public domain. When the surveys extended from two different points meet they do not fit together; fractional tracts fill the gaps.

If you will pardon me for referring to my statement of five or six years ago, and read by the honorable member of the commission, I would like to state further that the difficulty with all that parceling or Land Office work in surveying is that the permanent determination of lines rests upon the stakes put in the ground. The lines do not rest upon determined latitudes and longitudes, or, in other terms, on determined parallels and meridians. Had an accurate trigonometric survey been prosecuted in conjunction with, but not subsequent to, the marking of the boundaries upon the ground, in that case the stakes if lost could have been accurately replaced; but the stakes having already been set at random and not by trigonometric methods, no subsequent triangulation can be of any value; lines must forever hereafter be determined by evidence of individuals who have previously known where the lines run when the marks on the ground are lost. Had the lines been projected by triangulation instead of by chain and compass, it is my opinion that the work would have been less expensive. It would also have been far more accurate, and lost lines could have been easily replaced, and much litigation would have been saved thereby. But it is now too late to

mend that error; the lines have been run, the stakes have been set, and rights have vested.

Again, if the work had been properly done in the first place by the methods which I have indicated, all of the surveys of the public lands could have been fully utilized in the construction of topographic maps, and a resurvey for the construction of maps would have been unnecessary.

Q. Now, if your system of triangulation had prevailed when these surveys were made, they could have been adapted to that system?

A. Certainly.

Q. And ought to have been?

A. Yes, sir; and it would have been a great saving of expense—millions of dollars.

Mr. HALE. Now, before we break up this morning, I want to go back to the question of authority. I think the committee now sees what you have in mind as to the scope of your present work. You have gone somewhat into topographical surveys and have mentioned geographic surveys as comprehending more than the topographical, and the geological survey as comprehending more than either.

Major POWELL. As comprehending both the others.

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Q. That is the kind of work you are engaged in, is it not?

A. Yes, sir.

Q. And that is your conception of a geological survey and a map based upon it, is it not?

A. Yes, sir.

Q. Now, let me carry your mind back to the statutes upon which you are acting, so that you may see just how far you are justified in that. They are embraced in the appropriation bills. In the appropriation bill for the year ending July 1, 1882, this is the language: "For the expenses of the geological survey and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain, to be expended under the direction of the Secretary of the Interior, $150,000." Under that language these surveys had not been extended or attempted to be extended into the old States?

A. No, sir.

Q. Now, the next year, in the appropriation bill for the year ending July 1, 1883, is this language: "For the geological survey and the classification of the public lands, and examination of the geological structure, mineral resources, and products of the national demain;" precisely like the other, with the additional words: "and to continue the preparation of a geological map of the United States." Now, was it under those words, which are the added words, that these surveys having in view such a geological map as you conceived that you were authorized to make, were given, and have been extended? Was it under the authority given by those words which I have read, "and to continue the preparation of geological map of the United States"?

A. Under the authority of that special clause of the act of 1882 for the expenditure of the fiscal year ending 1883.

Q. That is the only act, is it not?

A. That is the only one. Under that act we commenced work in the eastern portion of the United States. Prior to that we were doing work in the western portion of the United States.

The CHAIRMAN. In the Territories?

Major POWELL. Well, not necessarily.

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Q. There is no substitution of the words "of the United States" for "the national domain." The same words were used with reference to the national domain and the kind of work to be done that were used in the statutes before; but the words are "to continue the preparation of a geological map of the United States." Now, my recollection is that you had something to do with preparing that clause that was put into the bill in the House. What did you mean by the words "continue the preparation of the geological map of the United States?" It was not put in for authorizing the new work, but to "continue" something that had been going on.

A. A part of the map had been already constructed. All that portion [indicating], all Colorado, and this much [indicating] of New Mexico, this much [indicating] of California—all that portion had been constructed. Then various agencies had done something in the eastern portion of the United States, and it was to continue the work which had been done.

Q. But these surveys had been confined, either under the consolidated bureau or under the old surveys of Wheeler, Hayden, and yourself, to the national domain, had they not?

A. No, sir.

Q. What had you done outside?

A. The surveys under Clarence King, and Wheeler, and Hayden, and Powell, that were consolidated, were not by law restricted to the national domain. The acts designated the country to which we were to go, so that Hayden was at work in Colorado, &c., and my own was designated as the Colorado River and its tributaries, afterwards the Rocky Mountain region; King's was designated by parallels; Wheeler's was designated as west of the Hundredth Meridian. Now, when the geological survey was organized we did not understand whether or not we were, under that authority, allowed to make maps in States where there were no public lands, and hence we did not make such maps. But the law contemplated that maps should be made on the national domain. Can you refer to the first act—the act organizing the survey?

The CHAIRMAN. That was a separate act, was it not?

Major POWELL. No, sir; it was an appropriation bill.

Mr. LYMAN. That was in 1879, was it not?

Mr. HALE. It must have been in 1881.

Mr. LYMAN. I think it was in 1879.

Mr. HALE. The year ending June 30, 1880. [Reading:]

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That is all.

Major **Powell.** There is another clause; there must be.

Mr. **Hale.** [Reading:]

The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps, illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology.

Major **Powell.** That is all.

By Mr. **Hale**:

Q. Do you think that that extended it beyond the fundamental provision what it should cover?

A. I will explain to you what I understand. In the first place it declares there shall be a geological survey; in the second place it declares that we shall make geological maps.

Q. Now, at that point I find that the first thought that was given, or the first that is expressed, for extending this work (which really seems to comprehend a geological and topographical work, and to call for the preparation of a geological map of the United States) is in the added clause of 1883. Now, that will be a great geological map of the entire United States, if ever completed. Up to the time when this act took effect had there been any portion of a geological map of the United States prepared, any more than the separate maps of the different surveys made under the supervision of the gentlemen who directed them?

A. There had been this much of a map of the United States prepared anterior to the passage of the amendment: First, there was the work of the four antecedent surveys, which had been extended over States and Territories alike. Second, the Geological Survey was already authorized to go into States wherever there were public lands, as the former act was interpreted. Thus it could go into fully two-thirds of the United States, but could not go into the remaining third. In all of the public land States it could go, and was prosecuting work. The Geological Survey was therefore constructing a map of not less than two-thirds of the United States, and it was desired to continue the preparation of such map until it could be extended over the entire country.

Q. Well, if it was the intention to extend this vast work to the old States and take jurisdiction of such old States, why, instead of this clause "to continue the preparation of a geological map of the United States," did you not go on in terms and provide for the geological survey of the United States, to extend its topographic and geological work into all of the States at the Government's expense; trying to make the best point of what you seem to understand as a geological map? I am familiar with the debates, and certainly it did not occur to the members of the Senate, it did not so carry the idea, that this was to take upon itself the province of a survey in the old States. Now, in framing that language, why did not you put it in fairly and in terms?

A. Allow me. Perhaps you do not recollect the whole history of the matter. When the question was first raised about the extension they introduced a bill to that effect. That bill passed the House of Representatives, and was referred to the Senate. It returned to the calendar of the Senate, and did not pass, and finally the Appropriation Committee put this in the appropriation bill and it became a law.

Q. But they did not alter the language of those bills?

A. No, sir; only to the extent of the additional clause; several gentlemen of the House discussed the matter upon this view; and more than that, it was not discussed in the Senate; but the Senate Appropriation Committee called me before them, and I made explanation to them, in this room, of the purpose of the clause.

Q. That you expected that this would comprehend topographical and geographical work in the old States?

A. Yes, sir. I can recall your memory to it by just one fact. This language did not come from the House complete as it now stands. The amendment offered in the House was ruled out on a point of order and then modified, and the words which were ruled out described the going into these States, and that was corrected in this committee and went through the Senate with the correction put upon it by this committee, and then went back to the House of Representatives and was agreed to by the House.

Mr. HALE. Undoubtedly, in your restricted language.

Major POWELL. It was the amendment made by the Senate committee that went back to the House and was there approved under very peculiar conditions. It went out upon a point of order in the House and was restored in the Senate, and when it came back to the House the House did not even refer it to the conference committee, as I remember it now, but called up that separate amendment and voted upon that question without its being referred to the conference committee. That was the history of it.

The CHAIRMAN. Pardon me. Here is the bill as originally reported in the House. Now, then, when it got into the House and was acted upon there, it came to us in the Senate, and we struck out, in this committee, the words "the national domain," which I think you will recollect, and I think you will recollect how they came to be struck out and all about it.

Mr. HALE. Yes, sir.

By the CHAIRMAN:

Q. This left it "a geological map of the United States;" then, in conference, the House agreed to that?

A. No, sir; not in conference. The House agreed before it went to a conference committee.

Q. Well, it was agreed to in the House then?

A. Yes, sir.

Q. The history is very familiar to us.

A. I just meant to show that it was discussed in this committee.

Q. Oh, it was discussed elaborately in this committee, and with a full committee; every member was here and voted, I believe.

By Mr. HALE:

Q. Do you remember presenting to this committee any proposition by which, under that language, it would be claimed you could go on with your work in the old States?

A. I was called upon by the committee——

Q. Did you present that feature?

A. Yes, sir.

Q. Now, after that authority was given at that time, did not the Coast Survey, an old and established institution, go on doing interior triangulating work, which, if continued under the undoubted authority, would be the basis by your using it for making a geological map?

A. No, sir.

Q. Was it not doing geodetic work?

A. Not to such extent as to be sufficient as a basis for this geologic work.

Q. But was it not a work that could be made a basis for this?

A. No, sir; not unless extended and changed.

Q. You say it was a kind of work entirely distinct from what you would want?

A. The Coast Survey was doing these things: first, the triangulation of the coast; then, as an outgrowth of the work on this belt of triangles [indicating] which was carried out here, and there, and there, to connect the two coasts, a single belt of triangles across the continent; then it was extending a belt of triangles down the mountains toward the Mississippi River. In addition to that, the Coast Survey was authorized to do certain work for States. An appropriation was made for that purpose, but it was not making a general triangulation of the country; nor was it making a topographic map of the country.

Q. If your work is prosecuted in the scope that you have in mind to completion, to what extent will that be a geodetic survey, and may not their geodetic survey as well stop?

A. Wherever that work is projected we use their work, and do not have to do it again.

Q. That is what I wanted to come at—do not you utilize their work?

A. Yes, sir, so far as they go; but they were not making maps; they were not doing the topography; they were making a certain amount of triangulation across the country for their own purposes, which is what I call a geodetic purpose, for determining the figure of the earth.

Q. Then you are not working together for a common purpose?

A. There is a field where we have a common purpose.

Q. What is that?

A. So far as they do run across the country and along the coast we use their work and do not have to do it again. They do not make a map; they establish certain points which we use.

Q. How many years do you think that it will take to make the geological map of the compass and scope that you contemplate now?

A. About twenty-four years.

Q. That will be all-embracing; it will take in the entire area of the United States?

A. Yes, sir.

Q. Including States and Territories?

A. Yes, sir.

Q. Including Alaska?

A. Not including Alaska.

By the CHAIRMAN:

Q. How much money do you spend annually of your appropriation in this triangulation?

A. A small amount in triangulation.

Q. What amount have you expended in the annual work of triangulation, probably?

A. About fifteen thousand dollars.

Q. You utilize the triangulation of the Coast and Geodetic Survey, so far as it goes. What is your judgment as to where that can best be done? Suppose we should consider that it was an unwise thing to duplicate these works; but, as I understand you, it is not duplicated. In other words, do you consider work now being done by the Coast Survey in that direction as a work that is valuable?

A. Most certainly; most assuredly.

Q. Is it your judgment that it should be continued?

A. Yes, sir; it should be continued.

Q. And wherever it comes in contact with you in any way you utilize it?

A. We do; and they furnish it without hesitation.

Q. And you dove-tail it wherever you can?

A. Yes, sir.

Q. And it is accurate as far as it goes?

A. Yes, sir.

By Mr. HERBERT:

Q. Major Powell, have you in your mind any plan of operations for the completion of this map? How do you propose to carry on the work; where first, where next, and in what order?

A. In the first place, I am trying to connect detached portions of work in the far West. Parties are at work in that region. Then I expect to expand from these districts where work has already been done [indicating upon the map].

Q. Please describe in words, so that the stenographer can take it.

A. It is proposed, then, to start from several centers where base-lines have been measured, and where base-lines are yet to be measured, in the eastern portion of the United States, and to extend from these several places until the work shall come together. The number of places already selected are about fifteen, but more are yet to be chosen.

Q. Please state where they are.

A. There is one in Massachusetts, one in New Jersey, one in Pennsylvania, one near where the five great States meet—Virginia, West Virginia, North Carolina, Tennessee, and Kentucky. Another of these starting points is in Alabama, still another in Texas, still another in southwest Missouri, northwest Arkansas, northeast corner of Indian Territory, and southeast corner of Kansas. But other starting points are to be selected in the future. Those mentioned are the only ones established at present.

Q. What was the purpose of establishing these different bases of operations?

A. The fundamental work of the survey cannot be properly executed from one base-line with sufficient accuracy. The distance between base-lines should be about 200 miles, in order that the triangulation of one may check that of the other. Should the work be extended to a great distance from one base-line and an error be made in the work, it could not be detected, and would be propagated and multiplied, and thus all subsequent work would be vitiated; that is, an error would propagate itself indefinitely and multiply itself.

Q. The principle is that you should begin at different points and come together so as to check errors?

A. Yes, sir; to secure accuracy.

Q. On what principle did you select these bases? Why did you select these particular places for them?

A. First, I have selected districts for the beginning of operations that are of special importance by reason of their being mining districts, districts in which coal and iron or other minerals are found. Second, districts are selected at proper intervals, and positions are determined by certain topographic characteristics—places where base-lines can be easily measured and the triangulation most economically expanded therefrom. Third, the particular spot for the beginning of a base-line is selected so that it shall be convenient to some telegraph station, in order that telegraphic connection may be made with the Observatory in Washington, or some other observatory, the latitude and longitude of which has been accurately determined; and this is done that the longitude of the spot may be obtained by the most accurate method.

Q. That is what I wanted to know. You spoke about the appropriation made by the State of Massachusetts, but you did not explain fully how you were connected with that survey. Does the State of Massachusetts have its officers and employés by whom and through whom this money is expended?

A. The State of Massachusetts appoints a commission to take charge of this work. That commission arranges with me to supervise the same; to furnish plans for carrying on the operations; to appoint the persons to do the work; to supervise it in its progress; to audit and approve the accounts which are sent to the commission and paid by the State.

Q. And that commission pays for it?

A. Yes, sir.

The CHAIRMAN. The State of New Jersey, also?

MAJOR POWELL. Yes, sir; but by a somewhat different plan. Instead of being managed by a commission in New Jersey it is managed by the State geologist.

Mr. LYMAN. Do they go on with the work?

Major POWELL. I had commenced work in Massachusetts before the State determined to make a state survey. Without my solicitation, and without my knowledge, certain gentlemen in Massachusetts presented this matter to the governor of the state. The governor in his message recommended that the state seize the opportunity to do work conjointly with the United States and make a more elaborate map than the United States were doing. It was for the purpose of serving certain local interests. The legislature took up the matter and made provision for a commission, as already explained, and also made an appropriation. In the mean time I was called before the legislature and explained to them the methods of operation, and gave them estimates of the cost. In previous years the legislature of Massachusetts had discussed the matter of the construction of a topographic map of the state, but the scientific men of the state who were called in as experts for their opinions disagreed as to the method upon which it should be made, and also as to the probable cost; so that the state was already ripe for action when the United States Geological Survey commenced operations in the Commonwealth. I have telephoned for the sheets of a part of that work to be brought here, and they are now present for examination.

Mr. HERBERT. I understand you were proceeding to make that geological map on a scale of 2 miles to 1 inch, and the State of Massachusetts said, "If you will enlarge that to 1 mile to 1 inch we will pay for it."

Major POWELL. Yes, sir; that they would pay the additional cost, which I estimated at $40,000.

By the CHAIRMAN:

Q. I notice in your letter addressed to General Meigs, as chairman of the committee of the Academy of Sciences, you say [reading]: "I beg permission to make a request, viz, that I may be permitted to present to the committee of the academy over which you preside certain opinions relating to the organization of the scientific work of the Government on a comprehensive plan, by which the work can be more thoroughly co-ordinated, more systematically prosecuted and more economically administered than at present, and to present the facts on which these opinions are founded. I beg permission also to state that I should esteem it a pleasure to answer any further inquiries, to any desired extent of detail, which the committee may wish to propound." Did you do so?

A. I did it only in part. At the time the committee of the academy held its session in Washington, I appeared before it for that purpose, but was in ill health, and I could only speak a few minutes, and was compelled to leave before I could fully set before that body the opinions which I desired to express. I was compelled to return to a dark room, where I had previously been confined, on account of difficulty with my eyes.

Q. Have you that statement in writing?

A. No, sir. I can have it ready to-morrow or next day, if desired.

Q. Can you have it ready by to-morrow at 10 o'clock?

A. I will have it ready if possible; if not, a part, at least, will be in writing, and, after reading that part, I can complete my statement orally. I will do the best I can.

Adjourned to Friday, December 5, at 10 o'clock a. m.

FRIDAY, *December* 5, 1884.

STATEMENT OF THE DIRECTOR OF THE GEOLOGICAL SURVEY—Continued.

The committee met pursuant to adjournment, at 10 o'clock a. m., in the room of the Committee on Appropriations, United States Senate.

Members of the joint committee all present, and the statement of Major Powell, director of the Geological Survey, was continued as follows:

By the CHAIRMAN (Senator Allison):

Q. Major Powell, have you prepared the statement which was suggested yesterday?

A. Yes, sir. May I ask the clerk of the committee to let me have a copy of the Revised Statutes? I shall need to refer to section 5581 of those statutes. I have prepared as brief a statement as possible in the very short time I had. I could have made it shorter had I been allowed more time.

Mr. CHAIRMAN. In response to your oral request at the session of yesterday, I present to the Commission my "opinions relating to the organization of the scientific work of the Government on a comprehensive plan, by which the work can be more thoroughly co-ordinated, more systematically prosecuted, and more economically administered than at present."

The scientific works prosecuted under the General Government of the United States, and in like manner prosecuted by other nations, may broadly but with sufficient accuracy be classed under two heads: In the first class are constructive works, such as the erection of public buildings, the improvement of rivers and harbors, and the construction of light-houses. In all of the operations of this class, in order that the work may be properly executed, scientific principles and methods must be observed; but such works chiefly involve problems of applied science. The second class of operations in which the Government of the United States, like all other civilized nations, is engaged, involve in their nature original investigation. They are designed in large part to furnish needed information to the people, and they involve not only questions of applied science, but, that the purpose for which they are prosecuted may be properly accomplished, new facts and principles must be discovered. Such an institution is the Geological Survey, the Coast and Geodetic Survey, the Signal Service or Meteorological Bureau, the Fish Commission, the National Museum, the Hydrographic Bureau, and the National Observatory. The functions of such Bureaus cannot properly be performed without scientific research, and their value depends upon the wisdom and efficiency of the methods of investigation pursued. It is to this second class, of purely scientific institutions, designed for and necessarily comprehending original research, for the purpose of giving information to the people, that I confine my remarks.

The operations of such institutions are exceedingly complex, and, from their very nature cannot be antecedently planned and executed according to such original plan. At every step of the work plans must necessarily be modified, as necessitated or suggested by discovered facts. It is therefore impossible by law to organize such operations; and more, it is impossible for the directors or superintendents of such work to lay out plans of operations which shall be a full guide to their assistants. A clear conception of the object to be attained, and a comprehensive knowledge of the principles to be used in the guidance of research are necessary; and beyond that, from time to time, as facts are discovered and the avenues of investigation are opened, the work is directed in its details. It will thus be seen that it is impossible to directly restrict or control these scientific operations by law. The general purpose of the work may be formulated in the statutes, and the operations may be limited by the appropriations made therefor, and this is as far as the statute itself can properly go; for, if the operations themselves could be formulated in law, the facts would already be known and the investigation would be unnecessary. It being impossible by statute to control or restrict the lines of investigation, as above shown, there is yet a control of the official personal organization which can properly be exercised by statutory provision, and a further control, superior to the immediate organization prosecuting the work, may be properly exercised in relation to the financial operations in the payment of employés, and in the purchase, use, and custody of public property and the supervision of accounts.

I beg permission to set forth certain facts which, I think, should be used as a guide in the establishment of such official organization and superior control.

In the first place, the investigations prosecuted by all of these scientific institutions are in their nature interrelated and interdependent. The success of one is dependent, to a large extent, upon the success of the others; and if at any time in the correlated investigations prosecuted by the General Government any one branch fails in its department, the other branches suffer therefrom to a greater or less extent.

For example, geodetic operations carried on throughout the world, and having for their purpose the determination of the figure of the earth, were for a long time prosecuted by refined trigonometric methods. But as the work progressed the problem was found to be more complex than was at first supposed, and elaborate gravity determinations were added to trigonometric methods. And it has quite lately been discovered that trigonometric and gravity methods must yet be supplemented by the determination of the geologic structure of lands, especially of mountains and mountain systems. Thus it has been found that the geographer cannot accomplish his work without appealing to the geologist for his knowledge. On the other hand, it has been found in the study of structural geology—and by that is meant the plan upon which the rocks composing the lands of a country are arranged—that it cannot be clearly understood and explained without the facts of geodesy. Sound geologic research, therefore, must progress hand in hand with sound geodetic research.

Again, in the prosecution of geodetic research, the parties thus engaged determine the exact position in latitude, longitude, and altitude of many points upon the surface of the earth. In the prosecution of a geologic survey of the same territory these same points must also be known; but more than that, their number must be vastly multiplied so that a map may be constructed setting forth the latitude, longitude, and altitude of all portions of the country surveyed. Where the geodetic survey establishes but hundreds of points the geologic survey must have millions of points established.

Again, the points to be used in the geodetic survey must necessarily be selected for that purpose. A general reconnaissance of the country over which such a survey is carried must be made, and the materials collected for at least a skeleton map. Thus it is that a skeleton map is necessary for a geodetic survey and a completed map for the geologic survey. In like manner it can be shown that the relations between geodetic and geologic work are manifold; and, still further, that the geodetic work and the geologic work have a great variety of connections with the other scientific works prosecuted by the General Government. It would require a volume to set forth all these relations and to show how completely the success of one is dependent upon the success of all.

It will thus be seen that the official organizations for these institutions should be co-ordinated, that they may work together and aid each other; and, further, as each is interested to a greater or less extent in the operations of the other, the organization should be such that one shall not be compelled to do that which is the proper function of another, and that no one shall be permitted to encroach upon the functions of another. As long as the several scientific commissions and Bureaus of the General Government are distributed through all the Departments of the Government—one in the War Department, another in the Navy, another in the Interior, another in the Treasury, &c.—each Bureau must necessarily to a large extent be autonomous; they must be self-governed, for it is a practical impossibility for any Secretary of a general Department to make such a study of the methods of scientific research as would warrant him in attempting their control. Hence, these institutions have in the past been to a great degree autonomous, and must under the same plan continue to be.

If the statements thus briefly made are correct, it follows that the first guiding principle to the proper official organization of the scientific work is as follows: The scientific institutions of the Government should be placed under one general management.

Again, as a necessity, scientific investigation must be controlled by the facts discovered from year to year, and from month to month, and from day to day. The operations of investigation, therefore, can only be controlled by the men who are actually performing the work; for example, the Director of the Geological Survey cannot possibly lay out the work for his assistants in detail. He can only set forth in a general way the object to be reached, the general methods to be pursued, and such plans must be held open to revision from time to time as the facts discovered by the investigators themselves may demand. He must, therefore, hold himself always in communication with his assistants, and ever be ready to entertain their suggestions, and there is always a probability that he will err more in the direction of rejecting wise suggestions than accepting unwise plans.

It is thus that, to a large extent, the plans of the work prosecuted by an organization for scientific research must originate with the experts and specialists who are themselves engaged in the investigation, and the most important function which the director of such an institution has to perform lies in the selection of the proper men, the specialists who have a genius for research. From the very nature of the work performed the plan of operations to a large extent must come up from the individuals who are doing the work, and can only to a limited extent originate with the director. Out of the multitude of plans and ideas thus suggested by a corps of specialists engaged in original research the superintendent or director selects such as he thinks wise, and is successful in his work to the degree in which he has a comprehensive knowledge of the subject.

If the above considerations are correct, the second guiding principle for controlling scientific work of the Government is as follows: The several bureaus engaged in research should be left free to prosecute such research in all its details without dictation from superior authority in respect to the methods of research to be used.

I beg to call the attention of the Commission to certain statements of the Committee of the National Academy of Sciences, which constitute a part of the record of the proceedings of this Commission.

These statements are as follows:

DEPARTMENT OF SCIENCE.

Your committee states only the general sentiment and wish of men of science when it says that its members believe the time is near when the country will demand the institution of a branch of the executive government devoted especially to the direction and control of all the purely scientific work of the Government. In this day the pursuit of science itself is, visibly to all men of education, directly connected with the promotion of the general welfare. * * * The members of your committee are conscious that placing these bureaus under one Department would not necessarily result in the proper co-ordination of their work, because the head of such Department would probably find it impracticable to enter into the consideration of all details necessary to that purpose. It appears to us that the evils already pointed out require in any case the organization of a permanent commission to prescribe a general policy for each of these bureaus. The functions of this commission would be—

(1) To examine, improve, and approve the plans of work proposed by the several Bureaus, and to revise their estimates in accordance with such plan The performance of this duty would require consultation with their chiefs, generally and separately, respecting the character of their work, and they should be members of the commission.

(2) To approve in detail the methods of expenditure of the appropriations.

(3) To recommend such measures as they deem necessary to the efficiency of the Bureaus under their supervision. It should, however, be understood that this commission is not charged with purely administrative responsibility.

It prescribes what shall be done and recommends any measures necessary to secure that object, but does not concern itself with administrative details.

It will be seen from the extract read that the learned members of the National Academy constituting that committee fully recognize the importance of a unified administration of the scientific Bureaus. The same committee further expresses the opinion that a department of science is desirable; but fearing that such a department cannot be organized at the present time, a commission is recommended, to be composed of a Secretary of one of the departments of the Government, the president of the National Academy of Sciences, the directors or superintendents of the scientific bureaus, a professor of mathematics from the Naval Observatory, an officer of the Engineer Corps, and two citizens of the United States, eminent as scientific men, to be appointed by the President.

Sympathizing fully with the general tenor of the recommendations of the Academy, I wish to present certain reasons for objecting to the constitution of the board of commissioners as recommended by that committee. The objection to such a board is twofold. In the first place, it would be composed of incongruous elements. A board composed of civil and military officers would, it is believed, be inharmonious, from the fact that military and civil methods of administration are entirely diverse and proceed upon diametrically opposed theories. The military officer plans and commands; the civil officer hears, weighs, and decides.

In the second place, the Board, as thus recommended, would be impracticable in its relations to the departments under which the several scientific bureaus are placed. Officers subordinate to the Secretary of War, and officers subordinate to other secretaries, together with officers having no other connection with the Government but as members of this Board, would have the practical control of the work so far as it could properly be controlled. And the secretaries themselves would simply be channels through which instructions to the bureau officers would be transmitted.

This, it is feared, would be irksome to executive officers composing the Cabinet of the President. It is a matter of record in the proceedings of this Commission that Professor Newcomb, of the Navy Department, and General Comstock, of the Army, withdrew from the committee of the National Academy at the request of their superior officers, the Secretaries of those Departments. It is presumable that this action was taken because the military Secretaries did not desire to have their subordinates deliberate upon questions of policy affecting the conduct of the Secretaries themselves; and this was entirely natural and proper from a military stand-point, where superior officers plan and command, and inferior officers obey and execute. In a civil department of the Government it would have been entirely in the course of things, and in no respect a violation of official proprieties, for subordinate officers to present plans, even of general policy, to their superiors.

Having thus briefly commented upon the plan of the Academy committee, I beg permission to suggest a plan which would not involve the same difficulties. There is in the organization of the General Government, an existing body of officers competent to co-ordinate the scientific work, with an organization peculiarly fitted to supervise the general plans, and yet leave the officers of the several scientific bureaus free to carry on the details of operations by scientific methods as they are developed from time to time. I refer to the Regents of the Smithsonian Institution. These Regents are composed of the Chief Justice, the Vice President, three members of the Senate, and three members of the House of Representatives, and six citizens. These Regents are appointed as follows (I quote from section 5581 of the Revised Statutes):

> The Regents to be selected shall be appointed as follows: the members of the Senate by the President thereof; the members of the House by ths Speaker thereof; and the six other persons by joint resolution of the Senate and House of Representatives.

This body of Regents appoint a Secretary of the Smithsonian Institution, who is their executive officer. If such of the scientific bureaus as should properly have a civil organization were placed under the direction of the Regents of the Smithsonian Institution, perhaps the best possible administration of the scientific work of the Government would thereby be secured, and the learning and administrative ability of the present Secretary of that Institution would furnish abundant assurance that the organization of these departments under a common head would at its inception be thorough and wise.

The history of the Smithsonian Institution, with its governing board constituted as above, is the best warrant that could be given for a wise administration of the scientific operations of the General Government.

The first Secretary of that Institution, Professor Henry, was one of the great scholars of his time, and under his administration the affairs of the Institution were conducted so as to meet with the approbation alike of the Congress of the United States, the learned men of the country, and the people at large. His successor, Professor Baird, one of the leading scholars of the world, has conducted the operations of the Institution as assistant secretary, and subsequently as Secretary, in such a manner that the Government of the United States has intrusted to him much larger and wider duties in the administration of the Fish Commission and the National Museum. It will thus be seen that the Board of Regents would constitute an able and efficient supervisory body, and it may always be expected that the executive officer of that Board would be a man thoroughly competent to execute such a trust.

I next come to the consideration of the subject as to what bureaus should be placed under this common organization.

Two of the bureaus already mentioned are now under the Smithsonian Institution, namely, the Fish Commission and the National Museum.

The Geological Survey could be very properly added to the number. Its relations to the National Museum are very intimate. All of its collections of rocks, ores, minerals, and fossils are deposited therein, and its laboratories for the study of these collections, chemic, physical, and paleontologic, are also in the National Museum, as they must necessarily be connected with the collections. This relation between the Geological Survey and the National Museum is not by virtue of organic law, but solely by convention between the Secretary of the Smithsonian Institution and the Director of the Geological Survey, and is a special courtesy to the Geological Survey extended by the Secretary of the Smithsonian Institution. In like manner the Geological Survey has intimate relations with the Fish Commission. In that Commission it is necessary to employ a corps of biologists; the paleontologists of the Geological Survey also constitute a corps of biologists. The biologists of the Fish Commission study the living forms in the existing bodies of water on and around this continent; the biologists of the Geological Survey study the fossil forms of the same region, some of which still exist, others of which have become extinct; and the biologic work of the two departments is so intimate that at times the biologists of the Fish Commission perform work for the geologists of the Survey, and at other times the biologists of the Survey perform work for the Fish Commission and the National Museum.

It is very clear, therefore, that the Geological Survey could appropriately be placed under the same management as the Fish Commission and the National Museum.

The Coast and Geodetic Survey must first be considered in its relations to certain other departments of scientific work. The committee of the Academy recommend the establishment of "a physical observatory to investigate the laws of solar and terrestrial radiation and their application to meteorology, with such other investigations in exact science as the Government might assign to it." And they also recommend that the functions of the Bureau of Weights and Measures, now performed by the Coast Survey, be extended so as to include electric measures, and that the whole be transferred to the new Bureau recommended. The Coast and Geodetic Survey already has under its charge the Bureau of Weights and Measures. It is also engaged in magnetic researches, and could appropriately undertake electric researches, and also the researches relating to solar and terrestrial radiation.

I do not think that it would be best to create a new organization for the purposes thus indicated, but that it would be the part of wisdom to enlarge the functions of the present organization of the Coast and Geodetic Survey to accomplish the desired purpose.

I have already mentioned that the National Observatory is one of the institutions engaged in original research of such a character that it should form one of the co-ordinated bureaus, but it would not be necessary to transfer it as an independent bureau. It might properly be consolidated with the Coast and Geodetic Survey. Under such a plan this Survey would have for its functions geodetic investigations, the methods of which are in part astronomic. It would also have the gravity investigations, and the investigations relating to solar and terrestrial radiation, which are also in part astronomic. It would also have the magnetic and electrical investigations. All of these lines of research are intimately related and profoundly interdependent.

I come now to a consideration of the survey of the immediate coast of the United States. The primary purpose of this survey is the construction of charts to be used by mariners. This survey of the coast proper is nearly completed, and should be finished by the present organization. When thus finished, the work of the Coast Survey on land will be practically ended, but the hydrographic operations must be permanently continued. In this hydrographic work a large corps of naval officers and seamen are employed under the Coast Survey, and the Navy is also engaged, under the organization of the Hydrographic Bureau, in conducting researches of like and related character off the coast. It is evident that this hydrographic work prosecuted by the Coast and Geodetic Survey is pre-eminently a naval work, from the fact that officers and seamen of the Navy are employed in its prosecution. The officers of the Navy are necessarily, and should be, the geographers of the sea. Statesmen agree that even in time of peace a naval establishment must be maintained. A school is supported by the General Government for the education and training of officers to command its navies. This training should be continued by practical operations at sea, not by engaging in unnecessary war, but in the navigation of the seas and the management of vessels; and while thus engaged the Navy may be appropriately and economically employed in the study of oceanic geography. I am therefore clearly of the opinion that the hydrographic work of the Coast and Geodetic Survey should be transferred to the Hydrographic Bureau of the Navy. As thus organized it would necessarily have a military administration and could not properly be placed with the other scientific bureaus enumerated above under one common management. There would yet necessarily be relations existing between the Bureau of Navigation and the other scientific bureaus, but they would be of a much less fundamental character and would be limited in scope, and the few relations thus existing could be properly adjusted by convention.

If the Signal Service is to have a military organization it would be unwise to directly associate it with bureaus with civil organizations, for reasons already stated. Should it be deemed wise to include it in the group of scientific institutions, it should then be reorganized on a civil basis.

The various lines of research enumerated in characterizing the scientific bureaus above are such as properly pertain to the functions of government in the common judgment of mankind. The warrant for this statement exists in the fact that the leading civilized governments of the world do, in fact, provide for the prosecution of such operations. The subject of the endowment of such research by government has been widely discussed by statesmen and by scholars in America and in Europe alike, and the wisdom of such endowment and the fundamental principles that should control such work have been again and again clearly enunciated. The actual practice of the several governments engaged in this work is to a large extent harmonious, but in some important particulars there is diversity of methods. In the British Government a part of the scientific research is controlled by organizations in the executive Departments; another part is controlled by scientific societies organized under royal charters, and receiving grants of money from the general Government. In the German states various methods are adopted, one of the most important of which is that the universities receive grants from the general government for scientific research. This latter method largely prevails in Russia, but in all of these countries the methods adopted in the United States are steadily gaining ground, and the practice of European governments is steadily following the precedents established in the United States.

The questions submitted by act of Congress to the deliberation of this Commission affect profoundly all of the important industries of the land. You are to decide for the people the best methods of utilizing the results of all scientific research, as they pertain to the welfare of the people of the United States, and your action, should it be confirmed by Congress, will ultimately affect the deepest interests of all the people, and the influence of your action will be exercised in promoting or retarding scientific research itself, which is the chief agency of civilization, and the results of which constitute the chief elements of civilization.

By Mr. HALE:

Q. Your recommendations then, Major, that these works be put under this one co-ordinate head, would cover the Geological Survey and Coast and Geodetic Survey, the work of the National Museum or Smithsonian Institution, as it is now prosecuted, and the National Observatory?

A. Yes, sir.

Q. You do not recommend including the Hydrographic Office?

A. I would recommend that the hydrographic work of the Coast Survey be transferred to the Navy.

Q. You make no recommendation in reference to the Signal Service?

A. I make no recommendation, except that it ought to have a civil organization if placed in co-ordinative bureaus. I was loath to volunteer any opinion about its internal organization.

Q. I so understand you.

A. Much more ought to have been stated. There is one point, however, I would like not to omit. Should by possibility such a plan be adopted, provision should be made for the present officers of the Naval Observatory, so that they may not lose their prerogatives, their rights as officers on the retired list and things of that kind, which they now have. They should be detailed to this work and retain their present official positions. You will remember that they are not civil officers.

Q. They would go there as part of the naval establishment?

A. Yes, sir; they are officers of the Navy, and it would be unjust to destroy their present relations to the Navy in this respect.

Mr. HERBERT. Major, a good deal of your argument this morning was directed to showing the impracticability of having unscientific officers in the management—a Cabinet officer, who is not a scientific man. Would those arguments apply to this simple direction as to a geological survey where it was to be begun? Do they not apply principally to those investigations which are purely scientific and for the discovery of unknown scientific facts?

Major POWELL. There are very many things which a Cabinet officer may direct, and in the practice of the Geological Survey does direct annually. At the beginning of the fiscal year the Director of the Geological Survey submits a plan of operations to the Secretary of the Interior. This plan, after it has been written by the Director and submitted to the Secretary of the Interior, is discussed between them, and finally the Secretary approves what is determined upon. Subsequent to that the Director of the Survey makes a monthly report to the Secretary as to what each party has done, in pursuance of the original plan submitted to the Secretary, from month to month, as the reports are made to the Director of the Survey by parties in the field. If at any time any important change of policy is made necessary by the development of facts, they are submitted to the Secretary. Further than that, there invariably arise certain questions in the Department which are submitted to the Geological Survey. For instance, if difficulties arise on Indian reservations of a certain character the director is instructed to send a geologist to these reservations and find out the facts and report the same to the Secretary of the Interior. Such difficulties arose this summer about the supposed occurrence of coal on two reservations, and outside persons wishing to mine the same. The Secretary of the Interior and officers under the Secretary who have control of disbursements revise and examine the accounts of the Geological Survey. There is a great deal of control which can be exercised. I tried very hard to differentiate between the control which can and that which cannot properly be exercised.

I shall be pleased if the stenographer will take a further statement down. I have presented a plan, which to me is only an ideal plan. There is yet another which I think will work very well. If it is deemed best to place these bureaus under a Department officer, a member of the Cabinet, it could be done by constituting the chiefs of those commissions and bureaus a board of co-ordination, to make their own report to the Secretary for his approval and ultimate direction, and I think the Department of the Interior would be one appropriate for such a board. It would be a board organized with altogether different relations to those recommended by the Academy. I feel quite sure from long observation in relation to various works that a mixed commission composed in part of officers of the military departments and of officers of the civil departments is an incongruous commission.

By Mr. HALE:

Q. Right here, major. I was very much interested with your discussion of the difficulties which beset such a commission as the Academy recommends—the troubles that would arise from inferior officers reporting to the Secretary, or taking jurisdiction, and civil and army officers and naval officers being thrown together. I was thinking about how that would work in other cases. Now, in the naval work that has been going on for a few years—a very important work, a work requiring investigations and skill, and to a degree experimental—there has been a Naval Advisory Board, made up in just this way, a conglomerate board. I do not think that any difficulty has been found with the action of that board. Are you familiar with their work?

A. I am not familiar with the operations of the commission; the result of their work I am familiar with.

Q. I believe they get along very well, and I believe it has been a very good thing in the progress of the work in the Navy thus far.

A. But it would be such a commission as in my last remarks I recommended, and not such as I at first discussed.

Q. It brings together experts.

A. But under the Navy.

Q. No, entirely out of the Navy; it brings together just such a combination of talent, and the Gun Foundry Board is made up in the same way, and that has extended its investigations through this country and abroad. It is largely supervisory with the Secretary. It is more than advisory practically, yet I think there is a great deal in what you say.

Mr. LOWRY. Your plan contemplates the immediate transfer of the hydrographic work to the Hydrographic Bureau of the Navy Department exclusively, and, as I understand it, the continuance of the geodetic work by the Coast and Geodetic Survey until the completion of the survey of the coast; does that contemplate the ultimate disintegration of the Coast Survey?

Major POWELL. It contemplates the completion of the coast survey proper by the Coast Survey. That would end when the work was finished, but it contemplates that they shall continue the geodetic work, and in addition supervise the astronomic work and the work of the various researches which are recommended by the Academy, and which they are already prosecuting in part.

Mr. HALE. You would add more than you would subtract?

Major POWELL. A good deal.

By Mr. LOWRY:

Q. And that such work will be continued by the Coast and Geodetic Survey?

A. That geodetic work is a work that will extend over a great many years—several generations—and before it is finished will be exceedingly expensive. But it ought to go on; it is a very important work. The operations of the Geological Survey cannot be delayed until that is finished, for in that case we would not have maps of the United States for two or three or more generations. If the operations are continued as now, within a generation we will have maps of the whole of the United States—topographic and geologic maps; topographic maps that will serve for military purposes; topographic maps that will serve for geologic purposes; topographic maps that will serve the purpose of civil engineers; topographic maps that will serve the purpose of cities and towns, and for all other purposes for which topographic maps are used.

Q. Has there never been found a duplication of work by the Coast and Geodetic Survey and the Geological Survey, or that the work of one impinged on the other? The point which challenged the attention of the Commission was the possibility of that. Now, in pursuance of some information from you and Professor Hilgard, I suggested to the Commission day before yesterday that I thought you took some common view by which any supposed impingement of the one upon the other could be accommodated.

A. Up to the present time we adjust that by convention between ourselves. That may at any time be interrupted.

Q. Can you state to the Commission at this time what view you have in reference to a practicable mode of overcoming any danger of a collision of that kind?

A. To adjust all difficulties between the Coast and Geodetic Surveys and the Geological Survey that may arise, the placing them together in one department is all that is necessary; and the operations of both would then come under the control of one man, and in my experience that control would be sufficient, because the Secretaries, so far as I know, invariably examine the work and plans sufficiently for that purpose.

Q. There is one point, a historical point, that I would like to be informed upon: When the United States Government relinquishes its title to lands in the States, it has no further dominion or control of that domain; I would like to know whether, at any time during the discussions which have taken place upon this question, the matter has been considered with reference to the power of Congress to carry this system of surveys into the States under the auspices of the Geological Bureau?

A. The matter has been twice discussed in the House at length, and I think once in the Senate; if I remember rightly, once in the Senate, on a resolution coming from the House to that effect.

The CHAIRMAN. Not at any great length, I think, Major Powell; some little debate took place on the subject—not much.

Major POWELL. I intended to have the whole history of that matter ready for the Commission, but it has been impossible to prepare it during the last twenty-four hours.

Mr. LOWRY. The Coast and Geodetic Survey draws to itself this power by reason of its being necessary to carry on the system of triangulation across the continent in order to complete the coast survey?

Mr. HALE. That is, it goes into different states under that power, with a view to a perfect system of coast survey operations?

Mr. LYMAN. Is it not empowered by statute to do that interior work? My impression is that it is.

Mr. LOWRY. My inquiry is addressed rather to the power of Congres to pass statutes to authorize the going into states in that way.

Mr. LYMAN. The theory is that the legislation is under the constitutional provision which authorizes Congress to regulate commerce between the states.

Mr. HALE. What would happen if, in the course of Major Powell's completion of this geological map, which he is now engaged upon, he should deem it necessary to make a thorough survey, a topographical survey, of any state in the Union which objected and protested against it and met in legislature and denied his power to go in there, saying: "This we propose to do ourselves; we will survey for ourselves, and we do not want the General Government to interfere"? What would happen then, Judge Lowry? That is simply carrying out your suggestion to its ultimate conclusion.

Mr. LOWRY. Yes; and as connected with that, the abstract question arose in my mind touching the power of Congress to provide for these disbursements, in making the surveys of the United States for the people of the states.

The CHAIRMAN. Well, you might ask what would happen still further if Major Powell should come to my farm and go to digging around to ascertain the particular structure of the land, and I should quietly say, "You must not do that; you are on my premises." What would be the effect of that?

Mr. LOWRY. The state, I suppose, could exercise the power of eminent domain and authorize the Government to do the work.

The CHAIRMAN. I am speaking now of the United States. I only wanted to ascertain Judge Lowry's views with reference to the powers of Congress; that is all.

Major POWELL. Mr. Chairman, may I say a word? The extension of the topographic and geologic surveys into the interior of the country rests on precisely the same basis as the extension of the geodetic surveys. They both come into the interior through the states, and are exactly on the same basis. As a matter of fact, in regard to the attitude of the states in this matter, the states, through their governors and their legislatures, and through various officers and citizens, are exceedingly urgent to have this work done; and if I were to go into the places where I am requested by state authorities, it would take a very much larger sum of money than is now appropriated. The practice of the General Government in this respect has been long established. It has prosecuted topographic and geologic surveys in California, Nevada, Colorado, Nebraska, and Kansas, and under the present Geological Survey in more than a dozen eastern states; in addition to this, for a long term of years, has prosecuted geodetic surveys in more than a half of the states of the Union. The precedent for such work has been fully established. The Congress of the United States has fully recognized the principles of its propriety by enacting laws from year to year to effect such surveys, and in addition to this the state authorities and the citizens of the states are very urgent that this work should be done.

Mr. HALE. I do not fancy that the situation suggested by my question is likely to occur. I have no doubt that the states, perhaps all of them, would be very glad to have the General Government conduct the surveys for them; it may not be right, but they want their share.

Major POWELL. In the state represented by Mr. Herbert they have a geological survey, and their officers have appeared in Washington for the purpose of getting us to do things which they cannot do themselves; and if you will look at the map which I presented the other day you will see that I have extended the operations of the survey into Alabama; and some of the operations are under the supervision of the State Geologist to-day; and to-day he is writing a report for the use of the Geological Survey.

The CHAIRMAN. That you do, I suppose, in many cases where you can utilize the state geologists and other scientific people.

Major POWELL. Yes, sir; there is in this law organizing the Geological Survey, under a proper construction, an interesting provision.

Mr. HALE. Let me ask you what law you refer to; that which was read yesterday?

Major POWELL. Yes, sir. The extension of the Geological Survey into the States was a measure that did not originate with myself. Personally, I should have been pleased not to have had it extended to the states for some reasons, simply scientific reasons, which I may not have time to mention; but most of the state geologists were exceedingly anxious that the United States should come in and do a certain class of work which they could not do themselves; and hence, I said to them then, it ought to be done in the method which will permit me to do only the work which you say cannot properly be done for years; and hence, while the Geological Survey may do all classes of geologic work on the national domain, under this law it can only do a particular class of work necessary to the construction of a geologic map. You see, if it is extended into the states under the provision that it shall make a geologic map, that carries into the states but a part of the geologic operations of the survey; and I have so explained it to the state geologists. The result is, that, one by one, the states are reorganizing their geologic surveys for the purpose of prosecuting this other part of the investigation, which, as I have explained, is untouched by the Geological Survey.

The CHAIRMAN. Explain that, please.

Major POWELL. That relates to the economic part of the work. I do not attempt to go into the States and say where beds of phosphates are; I do not go into the States and say on what particular land iron is to be found; or on what man's farm coal is to be found, or any other mineral. I do make a topographic survey, and upon that place the geologic formations, and then discuss the relations of the iron, and copper and zinc, and phosphates, &c., to those particular geologic formations. At that point the State Surveys come in and fix the values, methods of development, and other questions of the several articles by their own organizations. Upon that plan the states are reorganizing their surveys.

Mr. HALE. Now right there: In this survey, as applied to the national domain, as it has been understood, and not to the states, I would ask whether this investigation does not stop in the territories at the point where it would stop in the old states; or would you go on, in the territories, and take up the question of the economic?

Major POWELL. I would do that only to a limited extent, even in the territories; but we have done that to some extent. The difficulty in taking it up on the public domain, in the sense in which it is construed here, is that it is a question of the future, and cannot be taken up until the fundamental work is done, and so is necessarily relegated to the future. Yet, to some extent, we do take it up; especially in important mining districts and upon Indian reservations.

By Mr. LYMAN:

Q. If I am not mistaken, your monographs, which are large and full and valuable, are largely taken up with economic matters, especially in regard to the metals; but that is in the Territories?

A. Yes, sir.

Q. And there you have detailed explanations of mines?

A. Yes; but without entering into the subject of values.

By Mr. HERBERT:

Q. I understood you to say that this geodetic work would have to be prosecuted for many years to come yet, in order to complete it, and that it would be a great expense to the Government; I mean simply the geodetic work?

A. Yes, sir.

Q. And that the topographic work upon which you are engaged requires a thousand points where the other required hundreds, to be taken in the same method. Now, outside of the topography in which you are engaged, and of the geological map-making, what is the practical purpose of this extensive and expensive geodetic survey?

A. It is a very hard thing to answer fully what will be the practical result of any scientific work. The geodetic work—that is, that class of geodetic work which has for its function the determination of the figure of the earth, the general form of the earth—has many relations which are practical as distinguished from scientific. In the first place, it has relations to all astronomic work. The earth is the unit of mensuration, the unit for astronomic distances. The tables which are prepared for navigators, by which they determine the latitude and longitude at sea, are made up from elements in part derived from the consideration of the figure of the earth. The construction of geographic maps of the lands also involves elements derived from a knowledge of the figure of the earth; and absolutely correct maps cannot be made until the figure of the earth is accurately determined.

Again, it has relations to the work of geology in determining the structure of the rocks of the earth, the plan upon which the rocks of the lands are arranged, for scientific purposes and also for economic purposes.

Q. I understand, as you have very clearly explained, how this geodetic work is related to geology and geography; but my inquiry was, what is the practical purpose to be subserved by this extensive and expensive survey, outside of the geological and geographical work that you are doing?

A. There are three that occur to me as most important: The first consists in the fact that the results of geodetic computations enter into the construction of tables to be used by mariners; second, that the results of the determinations are to be used for charts to be constructed for mariners; the third is that these results are also to be used in constructing maps which have a multitude of practical values; and, fourthly, it is found that the most important scientific discoveries and determinations have a practical value in a multitude of ways. But perhaps the most practical value that a great scientific fact or principle may have subsists in its educating power—its power of improving the minds of the people.

Q. When the geodetic survey first went to the interior the idea was to run this system of triangulation directly across the continent, connecting the Atlantic and Pacific coasts, for the purpose of finding the shape of the earth in that direction. Now, have you any idea how much that cost?

A. Not at this moment; I could tell you by referring to the printed records, but cannot state without.

Mr. HERBERT. I would like to have you get that.

Mr. LYMAN. Professor Hilgard will give you that.

Mr. HERBERT. I wanted Major Powell's opinion as to that.

The CHAIRMAN. About $30,000 a year is appropriated for it, I think.

By Mr. HERBERT:

Q. Do you know whether any new fact has been discovered by this Survey, so far, that has been of any practical importance? What new fact of practical importance has been discovered by the expenditure of this money and the running of that system of triangulation across the continent?

A. It is incomplete yet; there has been only a beginning to the work. The ultimate result can hardly be predicated. It has not been carried so far as to obtain results yet.

Q. So far as you know, no fact of importance has yet been discovered by that system of triangulation?

A. Yes, sir; facts of importance have already been discovered by it: First, some very important facts relating to the Gulf Stream, affecting the navigation of the seas.

Q. Explain how that is.

A. The researches that relate to the navigation of the seas have their commercial value, or industrial value, in laying out tracks across the sea for vessels to follow, and in other ways; and in doing that the work of the Coast Survey and the work of the Hydrographic Bureau together have shortened the time and distance for vessels to a large extent.

Q. I think you misunderstand the question. That discovery of a shorter route which you speak of was made by studying the geography of the sea, was it not? But how does this system of triangulation running across the continent affect that?

A. Before that can be seen it must be understood that in connection with this they study the currents of the sea. The most important current in the navigation of the Atlantic is the great Gulf Stream; and this geodetic work has been utilized in determining the origin, and, to some extent, the nature of the Gulf Stream; but it is not easy out at sea to trace that Gulf Stream and discover its origin and effects; and one of the results—you asked for one—is to determine that there is an actual elevation at the origin or beginning of the Gulf Stream, in the Gulf of Mexico; that there is an elevation of the water by virtue of which the Gulf Stream has its source, takes its course, and is a gulf stream. That fact having been determined, the examination of the extent and character of the Gulf Stream belongs to a new line of research, and has to be taken up thereupon. The old lines are abandoned, and new lines of research are taken up for the purpose of determining the various facts; and that discovery will influence the charts which mariners use, and it has a practical, economic, and industrial effect to that extent.

Q. You have not yet explained, satisfactorily to my mind, what connection the triangulation between Pennsylvania and Colorado has with the fact of the Gulf Stream being elevated, or with the discovery of that fact.

A. That fact was discovered from the examination that was extended down the Appalachians—not the triangulation across to California, but from the triangulation of the other system. If you ask about the practical effect of the other line of trigonometric triangulation up to the present time, I know of no practical results; because it is all incomplete as yet.

Q. The discovery of the origin of the Gulf Stream, then, was the result of this system of triangulation which was made on the Appalachian range?

A. It was discovered by that and the survey of the coast combined. It was determined by the geodetic work of the Coast and Geodetic Survey.

Q. Has the system of triangulation that was made along the Appalachian range been connected with the Gulf, or did it not stop down in north Alabama? My question is, what connection did that work on the Appalachian range, the lower portion being in Tennessee or north Alabama, have with the course of the Gulf Stream down in the Caribbean Sea?

A. The geodetic work is composed of three parts: First, the determination of levels; second, the determination of geographic co-ordinates, latitude and longitude points; third, the determination of the effects of gravity at different points. In the operations of the Coast and Geodetic Survey the line of levels precedes everything else; they have to be established before the trigonometric points can be computed; hence they precede. Upon the map before you I have placed only the completed and published work of the Coast Survey. On that map you will see that the Appalachian work nearly connects with the Mississippi work, and the lines of levels have been run through to the Gulf of Mexico, as I am informed, connecting with all this work in New England from Cape Cod to the Gulf. The line of levels—I think several lines of levels, I must not be too positive as to the number—have been run through to the Gulf, with very great refinement, and the altitude of the Gulf above Cape Cod—I mean of the waters at mean tide—has been ascertained.

Q. Was not that fact ascertained by a simple coast survey, a line that runs down from Cape Cod to the Gulf?

A. I think not with that degree of refinement to insure accuracy. As I explained yesterday, all this geodetic work—trigonometric work of the United States by the Geological Survey and Coast Survey—must start from independent centers and be brought together, in order that they may check each other, that their errors may be detected; and a single line of triangulation and a single line of levels is never of sufficient accuracy to be of positive and permanent value.

Mr. LYMAN. One thing, Major. These points, so called, are the geodetic work, or series of triangulations, which have been begun in the transcontinental direction, and which have been spoken of in this committee as if they were something separate and distinct from the surveying. Now, am I right in saying that this work must, by somebody or at some time, be done, at any rate before the ultimate topographic survey can be completed?

Major POWELL. No, sir, I do not look upon it in that light. Triangulation is necessary before the ultimate topography can be completed. So far, that is true.

Mr. LYMAN. That is my point.

Major POWELL. But not this geodetic work. The triangulation for map-making purposes is one thing. The triangulation for geodetic purposes, or for determining the figure of the earth, is a very different thing. In the triangulation for map-making purposes a vast multitude of points are to be determined by methods less refined. The attempt is made not to introduce methods of refinement superior to the needs of the work. There is no necessity for determining a position to be placed upon the map within 10 feet where the line with which it is marked will itself represent 1,000 feet. So trigonometric methods for map-making purposes are very much less refined than for geodetic purposes, and very much less expensive. But the very same trigonometric points that are used for making the maps are also necessary as preliminary work to the geodetic survey. The Coast Survey has to make a preliminary triangulation of its work which is to a large extent the same as that used by the Geological Survey for its work. It goes into the field, and makes what it calls a reconnaissance survey, the cost of which, perhaps, and I speak with only a general knowledge of the matter, is about 40 per cent. of the whole work. This is for the purpose of selecting the points in the geodetic survey. In the reconnaissance or preliminary triangulations, say a hundred points are determined in a given area. Out of that hundred points it ultimately selects one or two or three to be occupied in the general scheme, and at those points extended observations are made. Observations are repeated and made with instruments of refinement at comparatively great expense; that is, at great expense as compared with the original determinations made by the Geological Survey. Now that preliminary reconnaissance is necessary for the geodetic work, and it is necessary for the Geological Survey; it is just in that point where the work of the Geological Survey overlaps the Coast and Geodetic Survey.

Mr. HALE. But you do not need to go on and make that refined work which the geodetic survey requires?

Major POWELL. No, sir. But if in the prosecution of the work the Coast and Geodetic Survey precedes the topographic work of the Geological Survey, we can use and do use the points determined in their preliminary survey as well as in their final geodetic work. In like manner, if the operations of the topographic survey under my charge precede the reconnaissance survey of that Bureau they can use our points for their preliminary work, and plan the great geodetic figures therefrom, and thus save the expense of the reconnaissance survey.

The CHAIRMAN. But do they?

Major POWELL. Up to the present time I do not know that they have.

By Mr. LYMAN:

Q. As I understand you, it is entirely one of degree and not of kind. That is to say, that the triangulation of the geodesy is simply a more accurate triangulation than that of the preliminary reconnaissance. Therefore I am right in saying that if you could just as well do that which depended on geodesy, you would prefer it, or you would full as lief have it?

A. Yes, sir; but the refinement would never be shown on our maps.

Q. Do you happen to know in the ordnance map of England, which has been going on now for nearly a hundred years, whether their triangles are laid down with map-making accuracy or with geodetic accuracy?

A. In certain lines with geodetic accuracy; in others, map-making accuracy. The survey of Great Britain differs fundamentally from the survey in this country.

Mr. LYMAN. That I know.

Major POWELL. It differs in purpose. Its primary purpose is the establishment of boundary lines of estates and properties. The General Government makes a survey and lays down the boundary lines of estates. That is its first object. The second object is to make maps useful for military purposes. Now, under the military tactics of the Napoleonic days armies were manœuvered in masses on comparatively small areas of ground; but the steady improvement in fire-arms has greatly changed military tactics, and now troops are deployed in long lines and battle-fields are spread over great areas. Under these circumstances it is no longer necessary to construct such elaborate military maps, and place upon them all the details of hedges, ditches, fences, wells, quarries, embankments, &c., that were supposed to be necessary in the old time. For scientific purposes, and for such economic purposes as maps are used for in America, all of the details supposed to be necessary in the construction of maps of battle fields are unnecessary. Again, it has been found that when maps are constructed with elaborate details of culture, the representation of all of these details soon becomes obsolete; the culture portion changes from year to year and from decade to decade. And when the conventional characters necessary for their representation are placed upon the map in great numbers, they greatly obscure the other elements representing natural topography and the more important cultural topography. Hence scientific men are condemning that old method of constructing maps, and are advocating the methods adopted in this country, especially by the Geological Survey. At the meeting of the "British Association" in Montreal and the "American Association" at Philadelphia, during the last summer, this subject was largely discussed by a number of English and American gentlemen, and I believe the method adopted by the Survey under my charge was universally approved.

By Mr. HALE:

Q. Has any part of the earth's surface been subjected to this geodetic work which the United States is now engaged in, such as it will be when completed?

A. No nation has fully completed its work. The British Government has completed that part of it, I think, for the United Kingdom. It has come in Europe, however, to be an international work to some extent.

Q. You think it has been completed on the British Isles?

A. It has, if I remember rightly. Other nations are going in, so that there is a general system extending over Europe and all of the countries by convention of parties or official arrangement.

Q. You look upon that as expensive but valuable work?

A. Yes, sir.

Q. It must be done?

A. Yes, sir.

Q. You expect that the work of the Geodetic Survey will be more permanent and more enduring, and extend into the future far beyond that of the geological maps?

A. It will in some respects. It is not easy to draw a comparison, relating to values, between the various lines of scientific research prosecuted under the auspices of the General Government. They all have scientific and practical values, and I have long entertained the opinion that a Government cannot do any scientific work of more value to the people at large than by causing the construction of proper topographic maps of the country. Such maps have a great variety of utilities. They are necessary for geologic purposes, that geologic formation may be properly represented and the people know where these formations are, and especially so represented that they may be able economically to discover the mineral values therein. They are of value for a great variety of engineering purposes. With good topographic maps any intelligent man may readily see how cities and towns and all industrial centers may be most economically connected by roads, railroads, and all classes of highways. There has, within late years, sprung up a great interest in topographic maps for another purpose. Wherever any large number of persons are domiciled on restricted areas of land, as they are in cities and the larger towns, the subsoil beneath such areas is speedily becoming contaminated with the germs of disease and death, and the question of water supply is one of the most important in wise scientific sanitation, and topographic maps are absolutely necessary for the determination of the problems involved. Again, in all low coast lands and in all interior swamp lands, which are of vast extent in all that portion of the United States affected by Quaternary glaciation, there are large areas to be ultimately drained and redeemed for agriculture, and when thus improved they will constitute a part of the most fertile lands of the country. The problem involved in the drainage of these lands is topographic, and topographic maps are demanded in all parts of the country for this purpose. Such maps also have a very wide scientific application in geology, geography, meteorology, natural history, and anthropology. It should be understood that topographic maps, like coast charts, must, after having been constructed, be maintained; that is, corrected from time to time as new artificial features are developed. A new town grows up, it should be placed upon the map; a new road is laid out, it also should be delineated. But such subsequent additions are comparatively inexpensive.

Q. And no conflict between the two?

A. No conflict between the two. Let me say further that the most advanced Governments of Europe are extending their work outside of their immediate domains. For example, England is carrying it, under a very extensive plan, into India. They are making a very extensive and enormously expensive work there.

By the CHAIRMAN:

Q. Major Powell, have you completed any section of this map which you are preparing?

A. Oh, yes, sir; a good many sheets.

Q. As it will be in the end?

A. Not of the geologic work.

Q. That is what I mean?

A. The topography goes first.

Q. Have you seen Professor Hilgard's maps?

A. No, sir; I have only compiled from published reports.

Q. Is he not making a map also?

A. He is making a map of the eastern portion of the United States. He does not go into the topography as we do. He commenced topographic work two or three years ago, and that piece of topography which is colored brown [indicating on the map] was done in the interior.

Q. Is that all?

A. Yes, sir, so far as I know. When the act passed Congress, containing the provision extending the work of the Geological Survey into the eastern portion of the United States, Mr. Hilgard thought that the Geodetic Survey was not to do such work, as I am informed.

Q. What is the character of the map which is being made in the Coast Survey?

A. That is a map, I think, such as a draftsman is in the habit of making. It is being copied like those in the Land Office, putting the position of towns, &c., on it without attempting to represent hills, valleys, and the like—just a geographic map.

Q. But intended to be accurate?

A. Yes, within that scope; but never going into the field for the purpose of making it accurate, but compiling it from what has been done, as other people have determined positions.

Q. So that that does not interfere with this at all?

A. No, sir.

Q. What value will that have?

A. I think it will be of especial value as an accurately compiled map, say for the Post-Office Department and for many purposes. In fact, I think that the Post-Office maps should be made more scientific than they have in the past.

By Mr. HALE:

Q. What is your idea as to the particular form that the geological map of the United States will take for public use?

A. I thank you for asking that question. I expected yesterday to explain some things of that nature which the general conversation prevented. I wish to explain that subject so that it may be understood just what we have in view and what we are planning. In the first place, we, too, make triangulation; in the second place, we make topographic maps as preliminary and incident to the Geological Survey. Now, to go on and answer your question, the map of the United States as planned at the present time, contemplates one sheet for each degree of territory—each degree of latitude and longitude. The work is being prosecuted on that plan for a large part of the territory of the United States. The scale of work to be represented on such sheets is $\frac{1}{250000}$; that is, the distances on the map multiplied by 250,000 will represent the distances in nature. The size of the sheets will be 20 by 16½ inches, and they will represent the topography as a basis for areal geology.

Q. About the size of that [indicating]?

A. I can show you the sheets. [After getting sheet.] That will cover a degree of latitude and longitude. The general plan is one sheet for every degree; but there are certain districts of country where the topography is too intricate to be properly done on that scale, and it is proposed that in such districts the scale shall be enlarged to $\frac{1}{125000}$; that is, that a distance on the map must be multiplied by 125,000 to equal the distance in nature. There are reasons other than intricacy of topography which determine the enlarged scale; certain districts are important because of great mining interests, and more elaborate maps are demanded; other districts are important because their water-sheds must be accurately delineated in planning works for the supply of water to cities and towns. Again, in other areas where the topography is exceedingly intricate, and especially where assisted by State funds, it is proposed to enlarge the scale to $\frac{1}{62500}$, or about one inch to the mile. This is the scale adopted in Massachusetts and in New Jersey, and will probably be adopted in Pennsylvania, though as yet no final arrangement has been made with regard to this State. These are the three scales upon which the work is being carried on, and upon which a little more than 600,000 square miles have already been surveyed. The United States, exclusive of Alaska, has an area of about 3,000,000 square miles, and more than 600,000 square miles has been thus mapped, or surveyed for the construction of maps. It is thus that I have a fair basis for an estimate of the ultimate cost, and it is upon this experience that I made the statement yesterday that I thought the work would be completed in a time not greater than twenty-four years.

Q. How many sheets on the plan that you have described will be required in the finally completed work of the geological maps?

A. About 2,600 sheets.

By the CHAIRMAN:

Q. Not to be a map, then, spread out like this [indicating]?

A. No, sir; only a map in small sheets. The purpose is eventually to have them for sale. As soon as we get them done they will be called for in separate sheets. The people of the country will want more sheets of their own districts, but they will be in such a shape that they can be bound, if so desired, by states.

Q. I was about to ask you that. If you make these in sections comprising the latitude and longitude, taking, for instance, the State of Massachusetts, with which state you seem to be in accord, won't they also be glad to have you get into one section the whole State of Massachusetts there?

A. Yes, sir; but when that is done the preparation of maps on smaller scales is a trivial matter in regard to expense. That is only a question of executing it in the office and having it lithographed. It is a trivial matter under present methods.

Mr. HALE. Out of this any state can get a complete map of its own territory at very small cost?

Major POWELL. Yes, sir.

Mr. HERBERT. When this map is completed will it be only a nature map, or will it take culture too?

Major POWELL. It will take certain features of culture. It takes all the highways, roads, and railroads, and it takes county lines, town lines, &c. It does not take all the particulars of culture.

Mr. HALE. Does it take bridges?

Major POWELL. No, sir.

Mr. **Herbert**. But it takes twenty-four years to complete it. What do you think of the accuracy of the first part of a map which you have taken twenty-four years to complete?

Major **Powell**. The culture will always have to be kept up. So far as the natural features are concerned it will never have to be changed. So far as changing the culture is concerned, after you have established natural points the change of the culture part of the map from time to time is a very small expense. Further, and in connection with that particular point, it may be stated that up to the organization of the present Geological Survey that work was put on stone. The work of Wheeler, Powell, King, &c.—that work was put on stone. That was due to the vigor with which this work was progressing and the demand for immediate results. That was one of the evils of the system and one of the arguments which I made for a co-ordination of the systems, which was finally accomplished. One of the arguments was that we were doing ephemeral work. Since that these sheets go on copper, and the copper belongs to the Government. In the printing on stone, one edition is printed off, and this stone is then cleaned off and smoothed down, and a new edition must have a new engraving, but the work is now permanent. On the present plan, those sheets go on copper. Now, copper is of such a nature, you can make changes at any time. It is a soft metal, malleable and mobile, so that you may erase a line or put a new line upon it, as the case may be, so that a practical mechanician can cut that town out or put a new town in, or if a road has been changed, he can change that road on the map; the natural features will remain—the rivers, the valleys, the hills, and so on; and it is easy to change the artificial features because you already have the natural features to which they are related.

By the **Chairman**:

Q. Twelve years, did you say, or twenty-four, to complete it?

A. Twenty-four; I have given that as the longest time.

Q. Of course that time could be shortened by enlarging the appropriations?

A. Yes; it is only a question of appropriations.

Q. That is to say, you have an appropriation of $300,000. That enables you to have five or six parties in the field?

A. I have twenty-seven.

Q. But you have them in five different portions of the country?

A. Yes, sir.

Q. If you double the appropriation of course you would double your force in the field?

A. Yes, sir; but much would depend upon the division of the appropriation. At present a little more than one-third, I think, of the appropropriation is used topographically.

Q. You spoke a moment ago of utilizing the state geologists of Alabama; you also utilized the state geologists of Massachusetts?

A. They have none.

Q. So that the force engaged there is your force entirely?

A. Yes, sir; except the force which they pay out of their appropriations, but that is under my control.

Q. And selected by yourself?

A. Selected by myself.

Q. Your own force, but they pay their proper share of it?

A. Yes, sir; I put upon the work, I think, three trained men whom we had before, and got most of the others through the civil service examination.

Q. This will enable you to make pretty rapid strides in Massachusetts?

A. Yes, sir; I hope to complete Massachusetts in three years.

Mr. HALE. You make it a rule, do you not, to get all that you can from the State?

Major Powell. Yes, and from every body else; and, let me explain, very much is contributed by the railroads in the country to this work in a curious manner. The work is greatly cheapened by reason of the railroads which exist in the country. One of the great elements of cost is the determination of altitudes. Every railroad has its profile. A network of railroads exists in a State, and I write to a railroad asking them to give me a profile of their road. They send me the profile. I take, say twenty or forty railroads, the system of roads of a state or a larger district of country, that form a net-work of lines running in many directions. The altitudes above the sea of two or more points on these lines is determined. Having that, the railroad lines are traced by their profiles, and wherever a crossing is reached the altitude of each road, as represented by their profiles and accompanying notes, is examined and compared. They may agree. If not, the error is noted. In like manner we go on from crossing to crossing throughout the whole system of interlacing roads, and when all agreements or disagreements are studied and compared it is usually found that the errors can be corrected by this inspection from the fact that it will be found that many of the errors are systematic. They belong to some one road which has used a datum point not properly determined, perhaps. All errors which cannot be reconciled by this inspection are reported to the chief engineers of the roads involved. They are interested, of course, in having correct profiles, and are pleased that we should detect their errors in order that they may correct them. Usually they do thus make the necessary examinations or resurveys and furnish us the results. The discrepancies found are rarely very great—from 1 to 5 feet, in the main—though occasionally larger errors are discovered of from 5 to 15 feet.

Mr. LYMAN. And you bring the roads to this plan?

Major POWELL. Much correspondence is necessary, but the officers of the roads treat us with great consideration and do all they can to furnish us the facts, and in some cases make expensive resurveys. A large correspondence in relation to this matter also sprang up with engineers and county surveyors and other persons throughout the United States. When it became known that we were thus determining the altitudes above the sea of all the cities and railroad towns of the United States and very many other important points, the persons to whom I have referred wished to know these altitudes. At last it was decided to publish it all in tabular form, constituting a dictionary of altitudes. I have that volume with me [showing it].

By Mr. HALE:

Q. That is, as far as you have gone?

A. That is, as far as we had gone at that time.

Q. Is that published as a public document?

A. Yes, sir.

The CHAIRMAN. You sell it at cost, and 10 per cent. added?

Major POWELL. I sell it at cost under the organic law of the Survey; the cost is 20 cents.

By Mr. **Herbert**:

Q. Have you found that these railroad engineers were practically correct?

A. At first I found many errors.

Q. Give us some idea as to how accurate they were.

A. Well, we consider an error of 6 feet something of great magnitude. In fact we correct them to inches before we get through.

Q. Was it common to find any of these altitudes as determined by railroad engineers as much as 6 feet in error?

A. To properly understand this latter it should be explained that the errors in these railroad levels may be grouped into three classes: First, the railroad may have started from some point called its datum point and assumed that that point was some altitude above the level of the sea, and in that assumption made an error. Such errors are of the greatest magnitude; they may be as great as 100 feet; and an error of this class is very easily detected, for the whole road then is too low or too high, as the case may be. Again, different sections of the road may have been surveyed by different engineers, and in joining the sections there is much liability to error. The errors at these junctions are of a second magnitude and may amount sometimes to 10 or 20 feet. The third class of errors are due to slovenly or imperfect work, and are incident to the leveling. The instrumentation may be imperfect, or the record may be slovenly kept. But these errors are comparatively small and are the most difficult to detect; and it is in cases of this kind that the railroads are compelled to do releveling.

There are two or three problems which we have in hand in the Geological Survey, which fall properly within our work, and which are contemplated in the phraseology of the act, "the classification of the public lands," &c. That classification of the public lands involves, among other things, the determination of the forest areas; and the areas of irrigable lands in that country where irrigation is necessary for agriculture, *i. e.*, the areas where irrigation is possible, together with the sources of water to be used in their supply. It also involves a classification of the pasturage lands. These all refer to the national domain, it must be understood, but so far as the timber areas are concerned, those are platted on the maps wherever they may be made, simply because the work can be done without additional expense. Give me the sheet of Massachusetts [addressing his clerk]. I have here a sheet taken from the plane-table as it is sent from the field before it is discussed in the office; one of the most difficult and expensive pieces of work—expensive because difficult. Where there are hills and mountains, map-making is of very little expense. Where the lines are low and the ground covered with forest, map-making is very expensive. You see there are no names here—just the work as done in the field. Now, these lines running through the sheet show the levels above the sea; they lie but 20 feet apart in verticality. These areas [indicating] are timber areas, as shown by the conventional sign. These are the lakes; swamp here; streams; the roads and town lines, &c.

Mr. **Hale**. Where is this; in eastern Massachusetts?

Major **Powell**. Yes, sir. Massachusetts is all growing up again to forest.

Mr. **Lyman**. Yes, we are going to be a great timber state.

By the **Chairman**:

Q. I do not know, Mr. Powell, that we wish to go into much further detail. I have no doubt you are doing an important work and doing it in a proper way, and, unless some gentleman desires to ask further questions, I think I will ask Major Powell to furnish us a statement of the number of employés, as soon as he can give them, in his local office here, and the compensation, and also the number in the field and their compensation. We do not care to have names; just simply the classification.

A. Properly there are very few men in the office. The scientific force is large,

Q. Give us your clerical and scientific force.

A. In the scientific force a gentleman might be in the field or in the office, as the case demands. These facts are published every year in my reports.

Q. Is it all in the Blue Book?

A. All my employés are in the Blue Book; but the ax-men and laborers, and others employed in the country as we go about, are not.

Q. We want the facts in as detailed a way as possible.

A. I will classify them and send them to you.

By Mr. LYMAN:

Q. In regard to the ordnance survey of England as connected with the geological survey; as I understand it, the ordnance survey has been going on for about one hundred years, and what you and I would call a topographical survey or geological survey was begun as a sort of amateur enterprise in about 1832, and was taken up by the Government and became part of the Government work. My point is this: Am I right in thinking that the method of the geological survey is to take the ordnance sheets as they are published, showing the topography of the country, and then to lay down on those sheets in colors the geological formations and structures?

A. That is it.

Q. In other words, in England, what we should call the geodetic survey, if you choose to call it so, makes the maps, and the geological survey concerns itself purely with geological and paleontological and mineralogical matters, and so on, and follows after the Government topographical survey, simply taking the maps and coloring them. That was all, was it not, major?

A. Yes, sir.

By Mr. HERBERT:

Q. Are those ordnance maps published?

A. Yes, sir; published and for sale.

Q. And would be just as useful for an invading as for a defending army?

A. Yes, sir.

Mr. HERBERT. That must be very useful to Von Moltke.

Letter from the Director of the Geological Survey, furnishing certain information desired by the committee.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, December 6, 1884.

SIR: In response to your request of the 5th instant I have the honor to submit herewith a statement showing the appropriation and expenditure by fiscal years of the several surveys of Hayden, Powell, King, and Wheeler, and the number of square miles covered respectively by each of those organizations.

I regret that it is not possible for me to furnish the committee with the information asked for in the second paragraph of your letter, viz, "the expense of printing, lithographing, and engraving for each of said surveys." As this class of work was paid for through the Public Printer, and no special amounts were appropriated therefor by Congress, it is not practicable at this late day to ascertain the respective sums with any degree of accuracy.

I am, with respect, your obedient servant,

J. W. POWELL,
Director.

Hon. W. B. ALLISON,
Chairman Joint Committee on Government Surveys, &c.

AMOUNTS APPROPRIATED.

Wheeler survey	$599,316 72
King survey of the fortieth parallel	386,711 85
Hayden survey of the Territories	720,000 00
Powell survey	279,000 00
United States Geological Survey, 1880	106,000 00
United States Geological Survey, 1881	156,000 00
United States Geological Survey, 1882	156,000 00
United States Geological Survey, 1883	254,940 00
United States Geological Survey, 1884	339,640 00
United States Geological Survey, 1885	489,040 00

AREAS SURVEYED.

United States Geographical Surveys West of One Hundredth Meridian (*Wheeler*).—Gross area surveyed by this organization, 359,000 square miles. Of this area 227,500 square miles was of the nature of reconnaissance work, and was published on a scale of 8 miles to 1 inch. The remaining area, 131,500 square miles, was of a more exact and detailed nature, and was published on a scale of 4 miles to 1 inch. Nearly all work was published in hachures.

United States Geological Exploration Fortieth Parallel (*King*).—Area surveyed by this organization, 86,390 square miles. This was published on a scale of 4 miles to 1 inch, in 300-foot contours.

United States Geological and Geographical Survey of the Territories (*Hayden*).—Area surveyed in systematic manner, 100,000 square miles. This was on a scale of 4 miles to 1 inch, in 200-foot contours. Besides this there was, during the years 1869 to 1872, inclusive, much reconnaissance work done, the area comprised in which, however, it is impracticable to estimate.

United States Geological and Geographical Survey Rocky Mountain Region (*Powell*).—Area surveyed, 67,000 square miles; published on a scale of $\frac{1}{250000}$, or about 4 miles to 1 inch, in 250-foot contours.

United States Geological Survey.—Area surveyed up to date, 184,200 square miles. This is embraced in the following States and Territories: Massachusetts, Connecticut, New York, New Jersey, Maryland, Virginia, West Virginia, North Carolina, Kentucky, Tennessee, Alabama, Georgia, Missouri, Kansas, Texas, New Mexico, Arizona, Nevada, Montana, Idaho, Wyoming, California, and Washington. That portion of this area lying in the sparsely settled Western States and Territories is to be published on a scale of $\frac{1}{250000}$, or 4 miles to 1 inch. That in the Mississippi Valley and the Southern Appalachian region on a scale of $\frac{1}{125000}$, or 2 miles to 1 inch, while that in the densely settled districts, when States assist, is to be published on a scale of $\frac{1}{62500}$, or about 1 mile to an inch. The interval between contours depends on the scale of the map, and amount of relief in the country, ranging from 200 feet in the mountains of the West to 10 feet in low coast regions.

SCHEDULE OF EMPLOYÉS OF THE UNITED STATES GEOLOGICAL SURVEY.

(Appended as per request of chairman of the committee.)

Office employés, December 6, 1884.

	Per annum.		Per annum.
Director	$6,000 00	3 clerks, each	$1,200 00
Executive officer	3,000 00	1 clerk	1,000 00
General assistant	3,000 00	4 clerks, each	900 00
Chief clerk	2,400 00	1 stenographer	900 00
Chief disbursing clerk	2,400 00	5 copyists, each	720 00
1 special disbursing agent	1,800 00	1 copyist	600 00
1 disbursing agent	1,800 00	1 engineer	1,000 00
1 disbursing agent	1,500 00	2 skilled laborers, each	900 00
Librarian	2,000 00	1 skilled laborer	720 00
Editor	1,800 00	1 skilled laborer	600 00
Photographer	1,800 00	1 watchman	840 00
1 assistant photographer	1,000 00	1 watchman	720 00
1 assistant photographer	900 00	4 watchmen, each	600 00
1 assistant photographer	720 00	2 laborers, each	720 00
1 assistant photographer	480 00	3 laborers, each	600 00
1 draftsman	1,600 00	3 laborers	480 00
1 draftsman	900 00	1 janitor	600 00
1 paleontologic draughtsman	1,000 00	5 messengers, each	480 00
3 clerks, each	1,400 00	3 charwomen, each	180 00

Scientific employés, September 20, 1884.

	Per annum.		Per annum.
6 geologists, each	$4,000 00	1 assistant paleontologist	$1,500 00
2 geologists, each	3,000 00	2 assistant paleontologists, each	1,200 00
1 geologist	2,700 00	1 assistant paleontologist	900 00
4 geologists, each	2,400 00	1 assistant paleontologist	840 00
4 geologists, each	2,000 00	1 assistant paleontologist	780 00
1 geologist	No salary	1 chemist	3,000 00
2 assistant geologists, each	1,800 00	2 chemists, each	2,000 00
5 assistant geologists, each	1,600 00	1 assistant chemist	1,800 00
4 assistant geologists, each	1,500 00	2 assistant chemists, each	1,500 00
2 assistant geologists, each	1,400 00	1 assistant chemist	1,200 00
6 assistant geologists, each	1,200 00	1 chief geographer	2,700 00
1 assistant geologist	1,000 00	3 geographers, each	2,500 00
1 assistant geologist	900 00	1 astronomer	2,000 00
1 assistant geologist	840 00	3 topographers, each	2,000 00
5 assistant geologists, each	*5 00	2 topographers, each	1,800 00
1 assistant geologist	*4 50	11 topographers, each	1,600 00
2 assistant geologists, each	*4 00	1 topographer	1,500 00
1 assistant geologic assistant	600 00	1 topographer	1,400 00
1 paleontologist	4,000 00	7 topographers, each	1,200 00
1 paleontologist	3,600 00	3 assistant topographers, each	1,000 00
1 paleontologist	2,400 00	6 assistant topographers, each	900 00
4 paleontologists, each	2,000 00	1 assistant topographer	840 00
1 paleontologist	No salary	23 assistant topographers, each	720 00
1 assistant paleontologist	1,800 00		

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* Per day.

Field employés not appointed by the Secretary of the Interior, but by chiefs of parties in the field, as they may be needed from time to time, to prosecute the work, September 30, 1884.

	Per month.		Per month.
2 field assistants	$100 00	12 cooks	$30 00
3 field assistants	85 00	1 cook	25 00
2 field assistants	70 00	1 janitor	10 00
3 field assistants	65 00	1 base-observer	35 00
3 field assistants	60 00	1 collector, with team	150 00
2 field assistants	55 00	1 collector, with team	140 00
14 field assistants	50 00	1 collector, with team	135 00
2 field assistants	45 00	1 collector, with team	120 00
8 field assistants	40 00	1 guide	*1 50
2 field assistants	39 00	1 packer	85 00
1 field assistant	35 00	1 packer	80 00
1 field assistant	30 00	4 packers	75 00
1 field assistant	*5 00	1 packer	67 00
1 barometer observer	50 00	1 packer	60 00
1 barometer observer	40 00	7 packers	55 00
2 barometer observers	30 00	4 packers	50 00
1 barometer observer	25 00	1 packer	40 00
1 barometer observer	15 00	6 packers	*2 00
3 rodmen	50 00	2 teamsters	60 00
4 rodmen	40 00	2 teamsters	55 00
7 rodmen	26 00	1 teamster	50 00
1 axman	30 00	1 teamster	45 00
1 axman	10 00	6 teamsters	40 00
1 herder	*6 75	7 teamsters	30 00
5 cooks	55 00	1 teamster	*2 00
7 cooks	50 00	1 woodsman	100 00
1 cook	45 00	1 woodsman	*3 00

* Per day.

Summary.

	No. of persons.
Appointed by the President, by and with the advice and consent of the Senate (Director)	1
Appointed by the Secretary of the Interior, on the recommendation of the Director of the Survey	134
Employed by the chiefs of parties in the field	148

Maj. J. W. POWELL, Director of the Geological Survey, then appeared and made a further statement, as follows:

Mr. CHAIRMAN: On Friday last the honorable the Acting Secretary of the Interior called my attention to a letter from yourself making certain inquiries relating to the transfer of the topographic work of the Geological Survey to the Coast and Geodetic Survey, and he requested me to prepare a statement of my opinions on the matter. This I have done, and it has been transmitted by the Acting Secretary to the chairman of the Commission through myself. The following is his letter of transmittal:

DEPARTMENT OF THE INTERIOR,
Washington, December 13, 1884.

SIR: I have the honor to acknowledge the receipt of your letter of the 9th instant on behalf of the Commission created by the sundry civil act of July last to consider the present organizations of the scientific bureaus therein named, with the view to secure greater efficiency and economy of administration of the same.

In response to your invitation for a presentation of the views of this Department in the matter, particularly as to the proposed transfer to the Coast Survey of certain work now in the charge of the Geological Survey, I transmit herewith a memorandum prepared by the Director of the Geological Survey, whose intimate knowledge and extended experience respecting the subject of your inquiry would seem to commend his views to the careful consideration of the Commission.

Very respectfully,

M. L. JOSLYN,
Acting Secretary.

Hon. WILLIAM B. ALLISON,
United States Senate.

Most civilized Governments undertake to prosecute the following classes of surveys, for purely scientific purposes in part, and for more directly economic purposes in part:

1. All civilized countries have prosecuted topographic surveys to a greater or less extent, and such surveys are more or less preliminary to all others. I have previously explained what a topographic survey is, and indicated its many values.

2. Geologic surveys are prosecuted, on scientific principles and by scientific methods, for the purpose of discovering economic values that exist in the geologic formations, such as rocks, ores, fertilizers, &c. The indurated formations which constitute the crust of the earth are decomposed at the surface, and so changed in appearance and constitution that no certain index is given to the underlying geologic structure. The formations which contain values are thus to a large extent masked, and it is the province of geology, as an applied science, to reveal these values. The interests involved in geology are of great magnitude. The mineral products of the United States for the year 1882 amounted in value to $454,000,000. The amount was a little greater for 1883, and will be a little less for 1884.

3. Geodetic surveys are also prosecuted. To a large extent they follow topographic surveys. The fundamental purpose of such surveys is to determine the figure of the earth—not only the flattening at the poles, but the general conformation; but they have other values, as the points determined may be used for cadastral purposes, as shown in the next paragraph.

4. Most nations are engaged in making cadastral surveys. The object of these surveys is to mark upon the ground the boundaries of estates. Such surveys are usually neglected until lands have become of great value, for their expense is great, and they are therefore not warranted ex-

cept in densely settled countries. To a large extent throughout the world the boundary lines of landed property, as determined by cadastral surveys are now being related to the points established in geodetic surveys. A geodetic survey is and should be carried on with extreme refinement, not only for reasons which inhere in the science of geodesy, but also that the established points used in fixing the boundaries of estates may be accurate. Before such a survey has been made the evidence relating to the position of boundary lines of land tracts is found in the marks upon the ground. If these marks are lost or controversy arises in relation to them, the settlement of such controversy rests upon parole evidence and such documentary evidence as the parties may produce. The evidence, therefore, is in the custody of the parties. But when a cadastral survey has been made the marks on the ground and the evidence by which the marks are identified when controversy arises or are re-established when lost, are in the custody of the Government. This may be clearly illustrated by recurring to the evidence of title. In countries where a system of record is established the Government is the custodian of the record, and transfers of title can only be permanently made by some legal procedure designed to perpetuate the evidence of the transfer on the official record. In like manner, when cadastral surveys are established, the surveys upon which they are made must be a matter of record in the surveyor's office, and the surveyor becomes the custodian of the marks upon the ground, and private individuals cannot change these marks of their own motion, even by convention of the interested parties; they must proceed by legal methods through the office of the surveyor.

5. In all of those countries, like the United States, which have had large areas of unoccupied land gradually settling up, another class of surveys has been initiated, namely, parceling surveys. The purpose of these surveys is to divide unoccupied lands into tracts, to be sold or given to the settlers thereon. When this system of surveys, known as Land Office or Rectangular Surveys, commenced in this country, it was the theory that they should result in the construction of topographic and geologic maps. The plan reported to Congress, by a commission, if I remember rightly, and adopted by Congress, had this end in view. The purpose was, first, to mark out upon the ground tracts for settlers, and to construct charts or plats of the same, which would be in fact maps, and at the same time to prepare with each such tract a geologic description, and also a general description of the soils, forests, &c., which would be of value to settlers. But as the General Government did not employ a scientific corps to do this—a work for specialists—but gave out the work by contract to bidders, all of the topographic and geologic portion of the work was neglected and became perfunctory; that is, it was made nominally but not actually. On the other hand, the marking out of the tracts upon the ground was executed in but an imperfect manner, because rude, unscientific methods were used; nevertheless, such surveys were of practical value, for many million acres of land were actually marked out on the ground, and such lands have been conveyed by the General Government to individuals, and are in the actual possession of these individuals.

In some countries all of the five classes of survey enumerated above are recognized; in most, however, the parceling surveys are unknown, for obvious reasons. In many countries parceling surveys have preceded all others. Then topographic surveys have been made; then cadastral surveys, and finally geodetic surveys. But there has been some diversity in the order in which they have been instituted and executed.

Maj. J. W. POWELL, Director of the Geological Survey, then appeared and made a further statement, as follows:

Mr. CHAIRMAN: On Friday last the honorable the Acting Secretary of the Interior called my attention to a letter from yourself making certain inquiries relating to the transfer of the topographic work of the Geological Survey to the Coast and Geodetic Survey, and he requested me to prepare a statement of my opinions on the matter. This I have done, and it has been transmitted by the Acting Secretary to the chairman of the Commission through myself. The following is his letter of transmittal:

DEPARTMENT OF THE INTERIOR,
Washington, December 13, 1884.

SIR: I have the honor to acknowledge the receipt of your letter of the 9th instant on behalf of the Commission created by the sundry civil act of July last to consider the present organizations of the scientific bureaus therein named, with the view to secure greater efficiency and economy of administration of the same.

In response to your invitation for a presentation of the views of this Department in the matter, particularly as to the proposed transfer to the Coast Survey of certain work now in the charge of the Geological Survey, I transmit herewith a memorandum prepared by the Director of the Geological Survey, whose intimate knowledge and extended experience respecting the subject of your inquiry would seem to commend his views to the careful consideration of the Commission.

Very respectfully,

M. L. JOSLYN,
Acting Secretary.

Hon. WILLIAM B. ALLISON,
United States Senate.

Most civilized Governments undertake to prosecute the following classes of surveys, for purely scientific purposes in part, and for more directly economic purposes in part:

1. All civilized countries have prosecuted topographic surveys to a greater or less extent, and such surveys are more or less preliminary to all others. I have previously explained what a topographic survey is, and indicated its many values.

2. Geologic surveys are prosecuted, on scientific principles and by scientific methods, for the purpose of discovering economic values that exist in the geologic formations, such as rocks, ores, fertilizers, &c. The indurated formations which constitute the crust of the earth are decomposed at the surface, and so changed in appearance and constitution that no certain index is given to the underlying geologic structure. The formations which contain values are thus to a large extent masked, and it is the province of geology, as an applied science, to reveal these values. The interests involved in geology are of great magnitude. The mineral products of the United States for the year 1882 amounted in value to $454,000,000. The amount was a little greater for 1883, and will be a little less for 1884.

3. Geodetic surveys are also prosecuted. To a large extent they follow topographic surveys. The fundamental purpose of such surveys is to determine the figure of the earth—not only the flattening at the poles, but the general conformation; but they have other values, as the points determined may be used for cadastral purposes, as shown in the next paragraph.

4. Most nations are engaged in making cadastral surveys. The object of these surveys is to mark upon the ground the boundaries of estates. Such surveys are usually neglected until lands have become of great value, for their expense is great, and they are therefore not warranted ex-

cept in densely settled countries. To a large extent throughout the world the boundary lines of landed property, as determined by cadastral surveys are now being related to the points established in geodetic surveys. A geodetic survey is and should be carried on with extreme refinement, not only for reasons which inhere in the science of geodesy, but also that the established points used in fixing the boundaries of estates may be accurate. Before such a survey has been made the evidence relating to the position of boundary lines of land tracts is found in the marks upon the ground. If these marks are lost or controversy arises in relation to them, the settlement of such controversy rests upon parole evidence and such documentary evidence as the parties may produce. The evidence, therefore, is in the custody of the parties. But when a cadastral survey has been made the marks on the ground and the evidence by which the marks are identified when controversy arises or are re-established when lost, are in the custody of the Government. This may be clearly illustrated by recurring to the evidence of title. In countries where a system of record is established the Government is the custodian of the record, and transfers of title can only be permanently made by some legal procedure designed to perpetuate the evidence of the transfer on the official record. In like manner, when cadastral surveys are established, the surveys upon which they are made must be a matter of record in the surveyor's office, and the surveyor becomes the custodian of the marks upon the ground, and private individuals cannot change these marks of their own motion, even by convention of the interested parties; they must proceed by legal methods through the office of the surveyor.

5. In all of those countries, like the United States, which have had large areas of unoccupied land gradually settling up, another class of surveys has been initiated, namely, parceling surveys. The purpose of these surveys is to divide unoccupied lands into tracts, to be sold or given to the settlers thereon. When this system of surveys, known as Land Office or Rectangular Surveys, commenced in this country, it was the theory that they should result in the construction of topographic and geologic maps. The plan reported to Congress, by a commission, if I remember rightly, and adopted by Congress, had this end in view. The purpose was, first, to mark out upon the ground tracts for settlers, and to construct charts or plats of the same, which would be in fact maps, and at the same time to prepare with each such tract a geologic description, and also a general description of the soils, forests, &c., which would be of value to settlers. But as the General Government did not employ a scientific corps to do this—a work for specialists—but gave out the work by contract to bidders, all of the topographic and geologic portion of the work was neglected and became perfunctory; that is, it was made nominally but not actually. On the other hand, the marking out of the tracts upon the ground was executed in but an imperfect manner, because rude, unscientific methods were used; nevertheless, such surveys were of practical value, for many million acres of land were actually marked out on the ground, and such lands have been conveyed by the General Government to individuals, and are in the actual possession of these individuals.

In some countries all of the five classes of survey enumerated above are recognized; in most, however, the parceling surveys are unknown, for obvious reasons. In many countries parceling surveys have preceded all others. Then topographic surveys have been made; then cadastral surveys, and finally geodetic surveys. But there has been some diversity in the order in which they have been instituted and executed.

In some countries the geodetic and cadastral surveys are under one organization; in others the geodetic and topographic surveys are under one organization; in still others the parceling surveys are under the same organization with the topographic surveys. All of these surveys may be combined, or each one may be carried on separately under a distinct organization. And it should be stated further that to a large extent topographic surveys have been military surveys, because the earliest and most urgent necessity for topographic maps was for such purpose.

Having thus set forth the distinct classes of survey, I now propose to indicate certain relations which exist between them in their execution.

If in the beginning of the history of a nation, when the lands are first parceled and distributed among the people (as they have been to a large extent in the United States since the establishment of the present land system), such surveys were to be inaugurated, they could all be taken up coincidently and co-ordinately, with a very large saving of expense.

In such a case the geodesy, that is, the refined triangulation, should first be made. Then should follow the parceling, or the measuring and marking of lines on the ground. Hand in hand with this, by the parties marking the lines on the ground, should go topography. The plats of townships, with the topography upon them, should be put in the hands of the geologist to mark the geologic formations, and the work would all be done. But such an ideal state of affairs has never existed, and may never exist. In most countries the parceling of the land has preceded all others, and usually the people have parceled it for themselves. Now, as the actual parceling of the lands is accomplished anterior to any other surveys, the relations of the geodetic, cadastral, topographic, and geologic surveys have to be established under new conditions, and new facts enter in to determine what their relations should be.

Cadastral and geodetic surveys are next considered in conjunction. These surveys are now demanded in America; frequent inquiries come to me from certain portions of the United States asking for information upon this matter. Cadastral survey shave, in the main, been based upon the triangulation which has been made in various countries for map-making purposes, but later experience shows that it is best to base them upon the triangulation made for geodetic purposes, as the latter is more accurate than the former. A cadastral survey, therefore, should follow, and be based upon a geodetic survey. It is clear from present experience that such surveys will be demanded, and the geodetic survey now in progress should anticipate that want, and fill it as fast as it arises. The geodetic survey, therefore, should go on. Its first purpose is the determination of the figure of the earth, but ultimately it will be of importance as a basis for cadastral surveys, and will then have great economic value, commensurate with its relations to all the landed property of the country.

Such a system of cadastral surveys has never been established by the General Government of the United States, but such a system is growing up locally, and will eventually prevail and in part become national in the following manner: Under State law, county courts, levy courts, and other local courts gradually acquire jurisdiction over these matters, and county or town or precinct surveyors are appointed or elected by the people, who do surveying for private persons, but such surveys thereby become official. The surveys thus made are marked upon the ground, and are further connected with certain landmarks in the country, established by the surveyors, consisting of stone or iron posts and other objects of this character. But such surveys are made by compass and chain, and usually involve errors of greater or less magnitude. When property acquires great value these errors become important, and more refined methods are demanded and more permanent datum points are needed, and the best points for this purpose are those connected with the grand triangulation of the country; already there is in some places a local demand for such a triangulation or geodetic survey for the establishment of these points. As this demand increases it will be gradually supplied by the General Government, for the interests involved are great as compared with the cost; and the General Government will perform its function, not by surveying the estates, but by establishing datum points, say one for each township, or a group for a county, to which the township or county surveys will all become related through the action of the local surveyors. It was in consideration of these facts that I made the statement to the Commission a few days ago that the geodetic survey of the country has great and enduring value.

The growth of institutions in America is from local centers, and this is especially true with relation to cadastral surveys. One part of these surveys, which can properly be done by townships, counties, and States, is already in progess over many parts of the country, as I have explained. The other part, the grand geodetic system of points to which the local surveys are to be ultimately connected, is also in progress under the organization known as the Coast and Geodetic Survey; and ultimately, as real estate enhances in value, and the refined operations of geodesy are extended over the country, the two will be connected. So far as I know, the Coast and Geodetic Survey has never, in its estimates or reports, set forth the extent and purpose of its work in the interior. It has estimated for the extension of its work from year to year over particular tracts, and having received appropriations for such work has reported what has been done; but so far as I know, it has never disclosed the ultimate purpose or extent of such work. It has constructed charts of the coast, but these charts are not such as I have described as topographic maps, but they are to a large extent cadastral maps; that is, they have marked on the maps the boundaries of estates, but have not gone on to complete a cadastral survey by marking the corresponding tracts upon the ground. But so far as may be understood from the work actually performed by the Coast and Geodetic Survey, it is manifest that its purpose is and has been to ultimately carry over the whole area of the United States a refined geodetic survey for scientific purposes, and for the further purpose of fixing the geodetic points necessary for the basis of local cadastral surveys.

I wish next to consider whether the State governments or the General Government should do this geodetic work.

In the various states of Europe geodetic work was carried on by the several states independently until within a few years. By this method local systems of geodesy were necessarily developed. It was discovered, first, that the methods used were of insufficient accuracy; second, that these inaccuracies could not be fully eradicated without connecting them into one grand system for the whole of Europe. These facts having been discovered, an international convention was called.

The following nations were represented in this international geodetic association: Baden, Bavaria, Denmark, France, Hesse, Holland, Italy, Austria, Prussia, Portugal, Roumania, Russia, Saxony, Switzerland, Spain, Wurtemburg, Belgium, and Norway and Sweden. In this the United Kingdom of Great Britain and Ireland did not come, for two reasons: first, because they had already made a new geodetic survey by the necessary refined methods; and, second, because their cadastral survey had already been related to the geodetic survey and their cadastral or "ordnance" maps constructed, as remarked by the honorable member of this Commission from Massachusetts (Mr. Lyman) the other day. But the countries that I have enumerated, through this convention, planned a general system of geodesy for the continent of Europe, and at the present time the various nations of Europe are executing this geodetic survey under the international plan; and as the work progresses they are executing final cadastral surveys and connecting them with the geodetic surveys. It should be still further remarked that the International Meridian Convention, held in Washington during the past summer, by which Convention the meridian of Greenwich was recommended as the prime meridian for all geographic purposes, was but a sequel to and grew out of the International Geodetic Association of Europe.

Experience then has shown in Europe that local systems of geodesy are not sufficiently refined. In my remarks the other day I stated that all trigonometric work should commence from as many independent centers as possible, in order that when connected each might serve as a correction upon the others. And it is thus that in Europe every nation is carrying on a work of geodesy, but on a general plan with the other nations, in order that when they are brought together the whole may be integrated into one great system, and the errors of all thereby eliminated. I think the statement thus made will fully make clear to this Commission that it is necessary in this country to have a national system of geodesy, and not a number of State systems. On the other hand, while the geodesy will be national, cadastral surveys will be local, as they are already in progress, being executed by local, city, county, or township surveyors.

I have already explained in brief the purposes of a geologic survey, and have also shown that it must be preceded by a topographic survey.

I have also shown that a geodetic survey must be preceded by a partial topographic survey, in explaining that a preliminary survey or reconnaissance is made for the purpose of selecting the points to be used in the final geodetic work.

The statement thus far made is necessary to a complete understanding of what I shall say in relation to the best agency for executing the topographic work in the United States, and to this subject I shall now address my remarks.

In most Governments three organizations are found: One for geodesy, one for topography, and one for geology. In the United States the geodetic organization, as distinct from the Coast Survey, has not executed topographic work, as I have defined that term, but the Coast Survey has made charts of the coast. These charts are maps of a peculiar character. The water areas are hydrographic maps, necessary for mariners, but in order to subserve this purpose properly certain land areas of the coast are included. On these land areas it is necessary that the salient land marks should be plotted, as guides to mariners, and so far the work is a proper chart for mariners. But much additional material is placed on these charts. To a large extent the charts are cadastral maps, on which are plotted estates. On some of the maps relief topography also is introduced to a greater or less extent, but usually this is lacking, and when introduced it is subordinate to the cadastral purposes of the chart. It will thus be seen that the so-called topographic maps of the Coast and Geodetic Survey are not what I have described as topographic maps, but rather what I have described as cadastral maps. The Coast Survey has not made a cadastral survey by surveying properties and establishing marks on the ground, but it has made cadastral maps. I think this statement presents the facts, and it matters not how terms are used.

Some four years ago, when it was found that the wording of the organic law of the Geological Survey did not permit that survey to come into the eastern portion of the United States, and when a proposition was introduced into Congress to correct that defect, the Coast Survey antagonized that proposition, and for the first year it was defeated. During this time the Coast Survey commenced a new class of work, namely, that small piece of topographic work proper to which I called the attention of the Commission the other day, the tract in Maryland and Virginia. But as soon as the work of the Geological Survey was extended into the eastern third of the United States, from which it had been previously excluded, the Coast and Geodetic Survey immediately withdrew from that class of work. It will thus be seen that that organization has, with the single exception I have mentioned, not attempted to do the class of work which the Geological Survey is doing; and, more than that, it has never had authority to do the class of work which I have defined as topographic.

On the other hand, the geologic surveys have executed topographic work to the extent of carrying it over about one-fifth of the United States, exclusive of Alaska. The geodetic work does not require the construction of a final map; the geologic work does require the construction of a final map. The Geodetic Survey requires the determination of many points, a few of which it uses in its grand triangulation; the Geological Survey requires a vast multiplicity of points; the number of points necessary for the Geodetic Survey has to be multiplied by thousands to subserve the purposes of the Geological Survey; but both surveys need more or less of this work as preliminary to their fundamental functions.

This multiplication of points necessary for the construction of the map is accomplished by the use of topographic methods, which have small expense as compared with geodetic methods. The triangulation necessary for topography is very cheap, and to a large extent is carried on by the topographers as a part of topographic work. Topography itself consists in main part of triangulation. Large triangles are measured for primary points. Within these figures new triangles are formed of smaller dimensions, and they are reduced in size through three, four, or five grades, until every little point in the area surveyed is fixed by triangulation. The altitudes also are in part fixed by triangulation, but this method of measurement is joined with the barometric method. Besides this triangulation and barometric measurement, there are a number of minor accessory methods used; but the whole thing is essentially triangulation, because trigonometric measurement is much more accurate and much less expensive than other methods. The principal points used in topographic triangulation are selected for topographic purposes and not for geodetic purposes, and it is rarely that the points best suited for one purpose are most useful for the other.

In Europe topographic surveying has not usually been intrusted to geodetic surveys or geologic surveys; first, because topographic surveys were made before the need of geologic surveys or geodetic surveys was felt; and, second, because topographic surveys were originally executed by army engineers for military purposes.

It has been said that topographic surveys with triangulation only sufficiently refined for map-making purposes have, in all European countries, preceded geodetic surveys; but there are three countries in which geodesy and topography are now simultaneously being extended over the same ground. These are Italy, Spain, and Prussia. In all three of these countries the geodesy is independent of the topography. For the topography they carry on a topographic triangulation, and construct the maps therefrom, and do not hold the topography back until the geodetic triangulation is completed. In these three countries, therefore, the geodesy is now following topography over the same ground.

I speak of a triangulation "only sufficiently refined for map-making purposes"; and it is necessary to explain why I have used this expression from time to time. Very many scientific operations involve measurements, and science is very largely mensuration, and mensuration should always be adapted in degree of refinement to the conditions under which it is used and to the purposes for which it is used. Years ago, before railroads were introduced into the great prairies of the West, farmers sold their corn to stock feeders sometimes at 10 cents per bushel. Under such circumstances two disinterested men would select a number of what they believed to be average shocks throughout a field. The corn in these shocks would be husked and measured, and the average of the field would thus be determined. After railroads were built and the Eastern and European markets opened to prairie farmers, they shelled their corn, cleaned it carefully, took it to market, and sold it by weight; and the method of measuring corn was thus much more refined. In each case it was adapted to the conditions and purposes of the measurement. This is a rude illustration of a fundamental principle, which goes through all scientific research, from the measurement of the amplitude of waves of light to the measurement of the orbits of planets. In complex scientific mensuration the several kinds of measurement used in the several parts of a great work should be correlated with each other; one part should not be more refined than another, and none of the parts should be more refined than is necessary for the purpose to be subserved. The reason for this is very simple. Every additional degree of refinement in measurements is attained only by additional expense of time and costly apparatus, and in general the expense increases at a ratio higher than the refinement. The principle which I have thus enunciated is the great economic law of scientific research.

As military engineers were the inventors of early topography, they developed methods of constructing maps suitable for their science. In later years topographic methods and plans of mapping have been changed, and these changes are radical, and are due to the influence of geologists, who have demanded better maps than those of the old military engineers. The military engineers have yielded to this demand by reason of the change in military science which I have previously explained.

I will confine my statements now to the United States. The Coast Survey has constructed charts of the coast. These maps are very elaborate and represent a vast system of cultural or artificial details; they are, therefore, very expensive; they are also difficult to understand. The geologic organizations of the Government have made topographic surveys in the interior to the extent of one-fifth of the territory. In the course of these surveys they have invented new methods of doing the work, and to a very important extent new methods of exhibiting the results on maps, by which the maps have become greatly simplified and much more easily understood by geologists, engineers, and the common people. Topography is no longer occult, and a topographic map is no longer a system of hieroglyphics; it is a plain representation of facts that all people may easily read. The experience in the United States, up to the present time, warrants this statement, that if the topography is kept under the control of geologists it will be executed better and at less expense than if placed under some other organization.

Again, there are other reasons why topography can be better executed by geologists than by any other class of persons. Geology is the most comprehensive science studied by man. It draws on all other sciences for its materials. Its most fundamental connection is with topography, because geology in all its branches has for its purpose, either directly or remotely, the explanation of the topography. The geologist explains the origin of all the natural features of the globe. First, he explains the origin of the lands as they rise from the midst of the seas. Then he explains the origin and position of mountains and hills, the origin and position of valleys, the origin and position of internal seas and lakes, the origin and position of springs, of brooks, and of rivers; and he classifies mountains, hills, valleys, lakes, and rivers by their structure and origin.

To do this it is as important to study the topography and to prepare topographic maps as it is for the physician or the physiologist to study the anatomy of the human system; and it is for this reason that topographic science rests upon the shoulders of geologists, and that geologists have revolutionized topographic science; and it is also through the geologist that geodetic science is at the present time being expanded, as I explained in my statement the other day. If the study of topography be divorced from geology at this stage, it will render topographic surveying perfunctory. All the vigor and energy which are devoted to topography in modern times arise from its geologic relations. No such relation exists between geodesy and topography, as is shown by the fact that a geodetic surveyor does not need a complete topographic map; he needs but the determination of a comparatively few points, which he plots on charts or plans, but he does not go on and construct the complete map of his work.

It will be manifest that the Coast and Geodetic Survey might adopt the methods of the Geological Survey instead of going on with its own. But by such an arrangement the work would be taken out of the hands of the inventors and put in charge of persons not in sympathy with these methods, because they would not fully understand the reasons for their adoption.

For more than fifteen years topographic work has been connected with geologic surveying under the auspices of the General Government. The Hayden, Wheeler, King, and Powell surveys were conducted in this manner. When the present organization was formed it was not merely a nominal but a real consolidation. All of the experts of the four antecedent corps were ultimately brought into the new work, and the men who originated the new topographic methods are still employed. I beg permission to express this opinion, that there has never been another such a corps organized in any country or at any time. The vigor and enthusiasm with which they push this work is tempered only by a scientific knowledge which comes of thorough training. The topographers constituting this corps were trained in their work by geologists, and some of them have acquired much knowledge in geology, and can render valuable assistance in the simpler portions of the geologic work.

Again, when map work has been done by the Coast Survey it has been found necessary to subject the work, before final publication, to a test with respect to its accuracy. Inspectors are employed to examine the work in the field by partial resurveys. Now, the Geological Survey furnishes the best possible system of inspection, and provides the best possible methods of determining the accuracy of the maps, from the fact that they are put into the hands of geologists whose business it is to go into the field, over all the ground, and to study the geologic formations with these maps in their hands, and if they are incorrect the geologic criticism speedily points out the errors. It is in this manner that the topography is controlled and raised to the highest standard. In the prosecution of the topographic work a vast multitude of lines are measured trigonometrically with far greater accuracy than they can be measured by chaining upon the ground. These measurements are subsequently used by the geologist in the construction of his sections, and thus he is saved the labor and expense of executing such measurements for himself. He takes the figures of the topographer to be used in the construction of his geologic sections, and it is in their use for this purpose that he determines their accuracy. The geographer makes a series of measurements in a region of country and depends upon the integrity of his instruments to decide their accuracy. Many of these lines are to be used again by the geologists as a measure of geologic formations. These formations are known to the geologist. A line here in one direction must be of the same length as a line there in another direction, because each subtends a certain geologic formation, and if such lines do not agree the geologist speedily detects the error, and that by methods unknown to the topographer. The topographer therefore makes measurements upon the ground for the geologist, and the geologist tests them for accuracy, and accepts them if they agree by his criterion, and if they do not, new measurements must be made.

It is thus that in the conduct of a geologic survey the work of the topographer is utilized. If the two branches of work are divorced the geologic survey loses the advantage of correction by criticism in detail, and would find it necessary to make numerous measurements for itself. This would cost a large share of the original expense of the work. If the topographic survey be severed from the Geological Survey, and a sum of money subtracted from its appropriation sufficient for another organization to execute the topography, the Geological Survey cannot prosecute its work with the remainder. It must have a large per cent. of the subtracted fund restored to its appropriation in order to do its work.

Again, in the topographic survey the topographers are draftsmen, for the man who does topographic work in the field must be able to put it upon the map. The geologists who perform the work of the Geological Survey are specialists of a high grade, to whom the highest salaries are paid. Such specialists are rarely draftsmen, and when they are it is not wise to employ them in drafting work, from the very fact that they are high-salaried men. But for the construction of their sections and other illustrations necessary to set forth the geology of the country, the topographers of the topographic survey are employed as draftsmen for the Geological Survey.

Again, geology demands more refined and accurate topography than any other science, and no other industrial need demands better work than economic geology. Some districts of country are geologically complex, others geologically simple. In those districts where the structure is exceedingly simple, less elaborate maps are needed; in those districts of country geologically complex, more elaborate maps are needed. Thus it happens that the topography has to be adjusted to geologic structure to meet the wants of geologic representation by maps. It has already been indicated by myself to this commission that the plan of topography adopted by the survey under my charge contemplates at least three distinct scales for this country. It may be further stated here that there are a few points of especial importance to the geologist, where the scale must be still more enlarged. For example, during the past year in the study of Mount Shasta we made a survey on a large scale of a small district complex by reason of its being an area of great and recent volcanic activity, and this was necessary in order that the geologic facts might be properly represented. Again, in the study of the quicksilver districts of California we have constructed six maps of small areas on large scales, because the peculiar geologic structure of the country in which quicksilver ores are found demanded maps of this character. Again, in the study of the great silver districts of Nevada and Colorado, maps on a large scale have been constructed. There are many such small districts scattered throughout the United States where large-scale maps will be demanded; as, for example, in the anthracite districts of Pennsylvania, in the copper-bearing districts of Michigan, in the great Iron Mountain district of Missouri, in certain coal and iron districts of West Virginia, Kentucky, Tennessee, Alabama, &c., and in certain phosphate districts of the southeast coast and the Gulf coast; and especially will this be necessary in important artesian districts in the arid country of the West, and in irrigation districts of the same region.

There is yet another reason why the Geological Survey should control the topographic survey. The problems which arise in a geologic survey do not appear in some systematic geographic order, as from east to west or from north to south; but they arise in the course of research relating to geologic formations, which are arranged from below upward, and which outcrop at the surface of the earth in a geographic order apparently adventitious or capricious, but in a geologic order according to well-defined principles. The geologist studying such a formation must be transferred now to this part of the country and now to that, and geologic problems have to be taken up in the order demanded by that science. For this reason it becomes necessary to start geologic surveys now in one district, now in another. That division of the survey which is studying volcanic formations, having intimate relations with the gold and silver ores, examines a district, now in Nevada, again in California, again in Arizona, &c. The geologic formations which contain coal are scattered irregularly about the United States, and for the study of the whole coal system of the country the problem has to be attacked from many points, and proceeded with upon a plan which is determined by the outcrop of these formations in the several parts of the country. Unless the Geological Survey can conduct its topographic work according to its needs in this respect, its work must be greatly hampered. The Geological Survey would be shorn of much of its immediate and pressing value were it compelled to wait upon the operations of another bureau and extend its geologic operations over the country in geographic order.

I think that the facts which I have laid before the Commission warrant the following statement: First, that topography is more essential to the Geological Survey than to the Geodetic Survey; second, that the Geological Survey can execute the work more economically than the Geodetic Survey; third, that the efficiency of the Geological Survey will be greatly impaired by having the topography taken from it; fourth, that a topographic survey should precede a geodetic survey, and that in the prosecution of a geodetic survey economy will result therefrom; fifth, that if the topography be placed under the Geodetic Survey the relations between the two organizations will be rendered more complex than at present. For these reasons it would appear that the recommendation of the committee of the National Academy is wise. That recommendation is as follows:

"2. The Geological Survey [should] comprise the present Geological Survey with its organization unchanged."

The CHAIRMAN. Major Powell, will you state your views as to the purpose and propriety of furnishing points for States, as that subject has been up for consideration?

Major POWELL. When the topographic methods of the earlier geologic surveys which preceded the present organization were developed, the fact that they were economically made speedily attracted the attention of the various geologists working in the eastern portion of the United States. Prior to that time their chief efforts in the preparation of topographic maps were by plans known as the methods of military reconnaissance; though they had to a very limited extent attempted to base their work upon triangulation. The maps made by these methods were very unsatisfactory, and when they found us making good maps in the Far West they concluded to try our methods in the East. But in order to use topographic triangulation for this purpose they found it necessary to have certain points established in each State from whence they could start such surveys, and certain of the State geologists came to Washington and asked that some bureau might do this part of the work, and finally, by act of Congress, through an appropriation bill, the Coast Survey was authorized to furnish points for States. The appropriations made for the purpose, however, were very small, and the work has progressed slowly.

In the mean time these same State geologists and engineers thought it would be better if the entire map were made for them, and for this reason: They soon discovered that even for a small area it required a large corps of men operating together. They must have astronomers connected with some fixed observatory, and a triangulation corps, for almost the whole method of topography is by triangulation; and they must also have good draftsmen and good barometric observers, and good computers, and in order to do the work by the methods of the Geological Survey, though comparatively inexpensive, they must still have a large corps of persons at work contemporaneously. The State appropriations made annually were not sufficient for this purpose, and hence they asked that the work which was in progress in the West and in the public-land States should be extended over the country, and urged that what was done for two-thirds of the country should be done for the whole. But the Coast and Geodetic Survey still continues the work of furnishing points to the States, although the States themselves are no longer trying to do topographic work, and in but very few cases did they begin such work. As this topographic work is now organized and in progress in the States, there is but one left which asks that the work may be done, namely, Pennsylvania; and the State authorities of Pennsylvania have already entered into negotiations with the Geological Survey to have the topography done by that organization for the State, they offering to pay a portion of the expense, as certain other States are doing. Under these circumstances the points must be furnished to the Geological Survey if they are to be utilized.

But the Geological Survey is establishing its own points on a scale much greater than that by which they are furnished by the Geodetic

Survey. It should be observed that these points are furnished not as a part of the grand system of the Geodetic Survey, but they are determined by the comparatively inexpensive methods used in the Geological Survey in its triangulation for topography. The work, therefore, is not a part of the final Geodetic Survey, but is of use for topography and also for the preliminary reconnaissance necessary for the Geodetic Survey.

The engineers prosecuting this work under the Coast and Geodetic Survey are mainly persons who are locally interested in having such work done, and are connected with the colleges of the country or other institutions, and do the work incidentally and in addition to the duties which they perform for local institutions. But if this small amount of work should be transferred to the Geological Survey, there would be no objection to having it performed by these same persons. The Geological Survey utilizes local talent in the same manner as the Coast and Geodetic Survey.

As the States do not call for this work, it would be better if the Coast and Geodetic Survey were authorized to execute it on the call of the Geological Survey, or that the Geological Survey should be permitted to do it for itself. It matters little which method is followed, ultimately the Geological Survey will use it all.

By the CHAIRMAN:

Q. Have you any other remarks to make with reference to the coordination of these Bureaus?

Answer. I should be pleased to make some additional statements, from the fact that my first presentation of the subject was necessarily fragmentary.

In previous statements made to the Commission I have endeavored to fully set forth the relations which exist between the Coast and Geodetic Survey and the Geological Survey, and I think that I have shown that these relations are many, far-reaching, and fundamental. I have also shown, in a less perfect manner, that the relations existing between the Geological Survey and the National Museum and Fish Commission are in like manner many, far-reaching and fundamental. And though I have not dwelt upon the latter branch of the subject to such an extent as the former has been considered, yet I shall not enter upon it again, but content myself with the remark that the relations between the work under my charge and the work under the charge of Professor Baird are more complex than those which exist between the Coast and Geodetic Survey and the Geological Survey.

I shall now consider the relations which exist between the Signal Service and the Geological Survey.

The Signal Service was primarily an institution designed to develop military methods of signaling from point to point on the battle-field, and from place to place in strategic operations, or the movements of armies preliminary to the direct contest on the field. To this service there has been added the functions of a meteorologic or weather and climatic Bureau, the purpose of which is to investigate the laws especially relating to temperature, moisture, and the movements of the atmosphere. To these scientific functions is added the duty of applying the science developed by investigation to the practical advantage of the people, by informing them of coming storms, of impending changes in temperature, and of other facts, all of which have an important industrial bearing. It will thus be seen that the Signal Service is performing two functions in no way related; army signaling has nothing to do with the science of climate. I purpose to consider only the relations which exist between the meteorologic operations of that Bureau and the operations of the Geological Survey.

In climatic investigations topography is of fundamental importance. One of the principal instruments used in this work is the barometer. Its indications, known as the rise and fall of the barometer, depend on atmospheric pressure, which changes daily with the changing movements of the atmosphere. But there is another element which comes in to change the indications of the barometer, which is altitude or topography. Now, in practical operations those changes which are due to climate must be separated from those which are due to altitude, and hence the altitude of the barometer above the level of the sea must be known. For this reason the Signal Service is as much interested in the great system of leveling executed by the Geological Survey as is the survey itself; and as evidence of this it may be stated that the Signal Service was formerly engaged in the same system of co-ordinating the railroad levels of the country as was the Geological Survey preparatory to the publication of the "Dictionary of Altitudes," which I described the other day. But this is not all. The Signal Service has progressed in its investigations until at the present time it has developed certain great laws of atmospheric movement, by which it is enabled already to predict in a general way the movements of great storms over the country; and it is now desired to extend the investigation further. This prediction of the general movement only in part supplies the needs of the people for weather prophecies. In order to predict local frosts, rains, tornadoes, &c., more thoroughly it becomes necessary to consider the effect of all local topographic features, such as mountains, mountain ranges, and mountain systems; the effect of valleys, lakes, and marshes; the effect of forest areas; the effect of prairie areas; the effect of the areas of the great plains, and so forth. All these topographic characteristics come in to complicate the problem involved in the general laws which govern the movements of the atmosphere, and the Signal Service is already as much interested in the topographic survey of the United States as is the Geological Survey, and it seriously needs a topographic map of the whole country in order that it may plan its stations and methods of research to discover those laws of atmospheric motion which arise from local topographic conditions. Thus it is that the Signal Service is interested in the work of the Geological Survey.

On the other hand, the Geological Survey is correspondingly interested in the progress of researches under the Signal Service. The Geological Survey is engaged in determining the altitude above the sea of every square mile of surface of the entire country. In doing this work it employs two classes of instruments, spirit-levels in connection with instruments of triangulation, and barometers. Only the fundamental lines of levels are determined by spirit-level instruments, from the fact that this method is slow and expensive. It therefore uses the barometer for the purpose of determining the levels of all the vast multitude of minor points; but I have shown that the barometer is affected by climate as well as by altitude, and in the Geological Survey we have to separate the climatic effects from the hypsometric effects; that is, effects arising from altitude. In the Geological Survey, therefore, we are interested in the climatic investigations to such an extent that all these climatic effects must be thoroughly understood. There is at the present time in the topographic work of the Geological Survey a pressing need for the determination of the laws which effect changes in the barometer, and one of the leading geologists of the Survey has been for some time engaged in this branch of work, devising more accurate means of measuring altitudes with the barometer, and while engaged in that work he has been in constant consultation with Professor Abbe, of the Signal Service, who is a master of this science; and the Geological Survey has already published a volume on methods of hypsometric measurement with the barometer. In this work we are seriously crippled from the fact that we need a certain class of observations which I have not thought it wise to inaugurate, lest I should be considered to be entering upon the province of the Signal Service; but if the observations now taken by the Signal Service at Pike's Peak and other parts of the country could be slightly supplemented with little additional cost, the results of such observations could be utilized in our determination of the constants to be used in computing altitudes by barometric observations.

But again, the Geological Survey in the prosecution of its work must necessarily have barometric observations made in all parts of the country in which it is at work. These observations are of two classes. First, stations are established in the districts under survey, and at each station one or two persons are employed making observations with the barometer. The parties executing the topography and traveling over the country carry with them barometers and record their readings. On returning to the office the readings at the stations are compared with the readings of the traveling barometers, for the purpose of determining altitudes. Thus it is that the Geological Survey has many barometric stations. In like manner the Signal Service has many more barometric stations for its purposes. Whenever the Signal Service has such a station within an area under survey by the organization under my charge, we utilize the record of the Signal Service station as far as we possibly can. But their records are incomplete for our purpose. The observations should be made more frequently than is now the case, and at specific times during the day in such a manner as to coincide with the readings of the traveling parties; and, if the observations of the Signal Service could be made in this manner, it would be an important saving to the Geological Survey.

Again, the general subject of climate is a geologic subject. In America and throughout the civilized world climate is investigated by geologists. They are not primarily interested in the present climate, but are interested in the past climates, as they must necessarily discuss these climates in discussing the origin and nature of the geologic formations, which is the subject of their study. A large share of the geologic formations of the past have in part their origin, and in large part their characteristics, due to atmospheric and climatic conditions. But in order that they may study past climate they must necessarily first study present climate. Geology might be described as the science of the origin and development of the present climate of this earth. Four of the geologists of the Geological Survey and several of their assistants have made extensive climatic investigations, and four of them have published works on this subject. And I have myself published three volumes on geology, in each of which geologic climates were discussed. Thus it is that the Geological Survey is profoundly interested in the general problems of meteorology and in the operations of the Signal Service, and that the Signal Service is profoundly interested in the operations of the Geological Survey. Frequent conventions and consultations are held by the scientific men of the two bodies on subjects common to them both, and there is much correspondence between the two bureaus. The Signal Service and the Geological Survey should work for each other and with each other.

I shall now consider the relations of the Geological Survey to the National Observatory.

To execute an extended survey, such as is now in progress under the geologic organization, it is necessary to determine a great number of points by astronomic observation. For this purpose it is essential to have the co-operation of a standard, fixed observatory. To determine a longitude with the greatest precision, it is necessary to make a comparison of times of two clocks, one at the standard observatory and the other at the point to be determined. It is of interest that this method, which has superseded all others wherever there is telegraphic communication, is the invention of American astronomers, and was first used by them to measure the difference of longitude between Baltimore and Washington. It is desirable to connect, so far as possible, all determinations directly with a single observatory. The great advantage of telegraphic methods is that we can measure with almost as much ease and precision over thousands of miles at a step as over a single mile, and we can thus avoid the accumulation of errors which arise when we measure from place to place.

Again, to determine the latitude of a place with the zenith telescope, or indeed with any other field instrument, the declinations of a number of stars, generally differing for each place, must be known with astronomic precision. The positions of the stars tabulated in existing catalogues are not fully satisfactory for this purpose, because the determinations were frequently the work of imperfect instrumments compared with those of the present day, and because most of the stars are continually changing position. With the fine instruments now made, a single astronomer at a fixed observatory could in a few days measure the declinations of all the stars necessary to fix the position of one station. With the same means, I think, a single observatory could in a few years determine the position of all stars which would be required to complete the topographic map of the United States.

The observatory could also co-operate by training and practicing the observers of the Survey in the use of their field instruments, and by testing them and determining their constants with more accuracy than can be done in the field. All this work is of sufficient importance to be considered one of the principal objects of any observatory that Congress might found. Thus it is that the Geological Survey and the Astronomical Observatory are engaged in research by astronomic methods, and the two could co-operate to great advantage.

I have thus endeavored to show some of the more important relations which exist between the Geological Survey and the several Commissions and bureaus enumerated in my former statement to this commission as those that should be co-ordinated. It has not been possible in the brief statement to set forth all of the relations, but only the more important; many minor connections might be shown. In making the statement I have exhibited the relations of the other institutions to the Geological Survey from my standpoint as Director of the Geological Survey. I have shown that the interests of the Survey radiate into every one of the others; that the researches of the Geological Survey traverse the lines of all the other scientific investigations prosecuted by the General Government. It would be quite as easy, and the argument could thereby be made quite as strong, to commence with any other bureau and show its relation to the rest; and by so doing each one would appear to be more or less a center about which the others were gathered in interest. Science is a fabric of complex structure, and scientific research is by multifarious lines. Many are the ways to interrogate nature and discover her laws.

There are yet some general considerations for such an organization as I have recommended, to which I wish to call your attention. From time to time important scientific questions arise in the progress of legislation and administration, and under present circumstances there is no properly recognized scientific authority to which these questions can be referred. Such a body as I have advocated, or as contemplated in the general recommendations of the committee of the National Academy, could perform such functions with manifest advantage to the Government and the people.

There is in America a very large body of men engaged in original research and its application to industrial purposes. Those who prosecute the work under the auspices of the General Government constitute but a fraction of the great corps; but they perform an important part, from the fact that the whole body of research in progress in America is largely organized and co-ordinated by the researches in progress in Washington. The scientific men in Washington have a much more important function to perform than that of simply conducting the work immediately under their charge. At every step they are compelled to consider what others are doing, and to take advantage of the same. They thus come into intimate relations with all the scientific men of the country; and there are performed in Washington only those parts of the work which must necessarily be done here. Each of these Bureaus has an unofficial corps of scientific men co-operating with it, and the results of the work thus accomplished come up here to be organized, digested, and utilized. The co-ordination and guidance of all this vast body of work can be much more thoroughly accomplished if there is complete organization under the General Government, and a recognized department, board, or commission under which all the scientific works are placed.

It would be a grave mistake should the Government organizations seek to absorb or in any way control the whole body of scientific research in the country, or to do any scientific work that could and would probably be done by other organizations or by private enterprise. But there are certain classes of scientific work that can only be prosecuted by great Governments, and that are so intimately related to the industries of the country that there is an absolute demand for the same. To this last class belong all the researches now under the auspices of the General Government. It is only in the fields of research in which the Government is engaged that the Government institutions can co-ordinate the work of the country; but within that field the general influence of the national institutions will inexorably be dominant. Nevertheless, it should be understood that the Government institutions should aid and foster local enterprise, and the reaction of such local work will be advantageous and aid in preventing official research from becoming perfunctory and valueless. Impelled by these considerations, some of the scientific institutions of the Government have already accomplished much in promoting local research. In administering the affairs of the National Museum and Fish Commission, Professor Baird has done much to secure the organization of State fish commissions and the establishment of biologic laboratories in the educational institutions of the country, to prosecute biologic research relating to the duties of the institutions under his charge.

The Director of the Geological Survey has in like manner done all within his power to build up State geological surveys, and to aid the educational institutions of the country, and that is considered by him to be an important part of his work. Other of the scientific bureaus are also developing like methods of administration. The principle thus illustrated and enunciated should enter fundamentally into the plans and operations of all Government scientific institutions. Under such a stimulus it could be reasonably anticipated that the scientific work which I have but fragmentarily and imperfectly outlined would be conducted by a vast system of organizations and institutions scattered throughout the entire country. The United States Geological Survey will then be supplemented by State surveys in all the States of the Union, and geologic investigations will be prosecuted by many of the professors connected with the colleges and universities of the land. The biologic investigations of the Fish Commission will be supplemented by the several State commissions, and by the biologists of educational institutions. The geodetic work of the Coast and Geodetic Survey will be supplemented and completed by the cadastral surveys of city, county, and township surveyors. And there will result from the topographic and geologic work of the Geological Survey, the geodetic work of the Coast and Geodetic Survey, and the cadastral surveys of local official engineers, three great maps of the country: Topographic maps, geologic maps, and cadastral maps.

The science of meteorology, cultivated and promoted as it should be by the Meteorological Bureau, will also be cultivated by State meteorological bureaus, and until these local bureaus are established and operated in a manner properly correlated with the central institution, the full benefit of meteorological operations to the people will not be secured. The science of meteorology, also, will then be cultivated by all our institutions of learning and by many private individuals throughout the country.

The astronomic work of the General Government will, in like manner, be supplemented and connected with work of the same character carried on under the auspices of the educational institutions. And should it be deemed wise to inaugurate additional physical research, as recommended by the Academy, that work also would form but an integral part of the great work of physical research already in progress throughout the country through the agency of local educational institutions.

In this connection it should be further stated that all of this scientific research under national, State, and local patronage, cannot be controlled by some central authority, as an army by its general, from the fact that scientific men, competent to pursue original research, are peculiarly averse to dictation and official management. Scientific men spurn authority, but seek for co ordination. They realize the truth of the great fundamental principle of political economy, that no great work can be performed without a proper division of labor, and they are always anxious that their several labors may be fitted into the grand system of scientific operations for the development of knowledge. Hence they voluntarily associate themselves, and relegate one to another appropriate lines of research, and hold congresses for the purpose of integrating all this work into one grand movement toward the desired end.

Whenever the scientific works of the General Government fall out of the control of scientific men, and into the hands of officers or functionaries whose interest is not in all research, but only in official position and dignity, such a political institution for the advancement of science at once becomes severed from the great body of scientific men; it no longer takes a proper part in the great work to be done, and it speedily decays in influence and value.

The system of governmental scientific institutions which I have included in the suggested plan and the discussions relating thereto have had a long, slow growth, arising out of experienced wants. They relate to all the landed property of the United States, to all the irrigable and pasturage lands of the arid country, to the reclamation of all swamp lands, to the reclamation of all flood plains on the great rivers, and especially to the protection of the valley of the Mississippi; they relate to all the mining industries of the United States, to all the engineering industries of the United States in the construction of highways, works for the supply of water to towns and cities, and for the sanitation of towns and cities; they relate also, but less indirectly, to all the manufacturing establishments of the United States; they relate also to all the commerce of the United States on sea and on land; and they are speedily becoming related to all the agriculture of the United States, as that agriculture is dependent upon climate and weather. Through the Fish Commission they relate to the supply of food to the people of the United States. The steady increase in the value of land, the occupation for agricultural and other purposes of the wild pasturage lands of the far west, and the rapid increase of population together are steadily increasing the cost of animal food, and statesmen and political economists are contemplating with some degree of concern a condition of affairs which may arise in this country by which animal food may be subtracted from the subsistence of the poor because of its extreme cost. But the scientific men of the country, especially the biologists, have discovered a means by which this calamity may be averted. They know that every acre of sea, lake, and river is capable of producing more animal food than ten acres of land, and that in the future fish culture is to be a more important industry in this country than stock raising, and that that food which is now in large part a luxury upon the tables of the wealthy will eventually be the cheapest food for all the people.

I have dwelt rather upon the scientific side of this problem; but the utilitarian side is of no less importance, and I hope that it can be gathered from my remarks that all the great industries of the country are profoundly interested in the operations of the scientific institutions which I have mentioned. My reasons for considering these subjects rather more from the stand-point of science than from the stand-point of industrial economy have been these: The value of these institutions depends upon the scope of the work, the lines of investigation pursued, and the methods employed. If their operations are based on common-sense principles—that is, on scientific principles—their work may be of immeasurable value; if they fail from the scientific stand-point, the failure is complete, and all money invested in them is wasted. I have taken it for granted that statesmen understand the importance of this work, its scientific and utilitarian value, which are ultimately identical.

It is in view of the facts thus stated and the principles thus enunciated that the recommendations which I have made to the Commission have been framed.

I consider it, Mr. Chairman, a great privilege to have been permitted to present my views to the Commission at such length; and I deem it an omen of prosperity for the scientific work of the country that the Commission should engage in an investigation so searching and so comprehensive as the one it is now conducting, and that the gentlemen of the Commission should be willing to devote so much time and labor to the performance of their task. I am sure that the many scientific men in this country, whose researches are far-reaching and whose influence permeates the land, are awaiting the result of your delibertions with earnest expectation that some wise system of organizing and prosecuting the vast researches in which this Government is engaged, will be devised.

The investigations carried on by a committee of the House of Representatives, five years ago, resulted in important and radical changes in the administration of the scientific work of the Government, and the changes then made meet with universal approbation. If the work thus begun can be continued through the labors of this Commission, and all of the scientific operations of the Government placed under efficient and proper control, scientific research will be established in America upon such a basis that the best and greatest results will accrue therefrom. The harvest that comes from well-directed and thorough scientific research has no fleeting value, but abides through the years, as the greatest agency for the welfare of mankind.

Maj. J. W. Powell then appeared, and continued his statement as follows:

By Mr. LYMAN:

Question. Major, on the 166th page, about eight lines from the bottom, in your statement, speaking of the Coast Survey, you say: "To a large extent the charts are cadastral maps, on which are platted estates." Would you not wish to modify that statement a little? As I understand it they only put in the estates in this sense, that they draw the fences and indicate the positions of houses, roads, &c., that connect. Now the fences might not have anything to do with the estates, so that the cadastral map, in the European sense of making what they called the Domesday-Book, in the Middle Ages, could not be constructed from that kind of a map?

Answer. Oh, no, sir; I think subsequently I have made that clear.

Mr. LYMAN. I see you have on the 167th page: "The Coast Survey has not made a cadastral survey by surveying properties and establishing marks on the ground, but it has made cadastral maps."

Major POWELL. Yes, sir.

Q. I noted that modification; but, as you understand, it would not be proper to say that they have put in estates as you see them indicated in town maps?

A. They have not made a cadastral map by looking up titles and plotting the boundaries of properties described in titles; but they have marked out the essential features of estates, such as the houses, the fields, the private roads, and various matters of that nature which belong to what I have defined as a cadastral map and which do not belong to what I have defined as a topographic map. It should be understood that topography means a description of places, and that the term "topographic" might well enough be used to describe what I have called a cadastral map.

Q. That is minute topography—as I suppose you might call it?

A. Yes, sir; you might call it topography, but it would not be topography in the sense in which I have used the term and in which I have defined the term. Etymologically, topography means a description of places. We may describe places on maps by their natural characteristics or by their cultural characteristics, and I have used the term "topography" to mean a cartographic description of the country by its natural characteristics—its mountains, hills, valleys, streams, bodies of water, &c.—together with certain cultural features, such as highways, boundary lines of townships, counties, States, &c. But where a chart is constructed in such a manner as to a large extent to neglect the natural characteristics by placing upon the chart the boundaries and improvements of estates, I have called that a cadastral map, even when it is not based upon a cadastral survey—that is, a survey intended to mark the boundary lines of estates upon the ground.

Q. Then, on page 167, at the beginning of the second paragraph; "On the other hand, the geological surveys have executed topographic work to the extent of carrying it over about one-fifth of the United States, exclusive of Alaska." Please tell the committee, if you can conveniently to do so, over what extent of that one-fifth of surveyed ground the geology has been put in; that is to say, the formations have been indicated. Perhaps you have not the figures so that you can tell to-day.

A. Over that area the geological formations have been plotted.

Q. Entirely?

A. Yes, sir; I think there is little exception.

By the CHAIRMAN:

Q. That is to say, where the topographic maps are complete the geological work is also complete?

A. It is also completed practically to the extent that we are able to plot upon the map the geologic periods, as they are called by the geologist. There may be some final work here and there in adjusting the parts. But the work of a geologic survey is but fairly begun at that stage.

By Mr. LYMAN:

Q. Then, on the 169th page, first paragraph, second line: "Geology is the most comprehensive science studied by man"; and then you go on to make very important deductions from that, and show very clearly the connection of geology with meteorology, with topography, with astronomy, and with other branches; and then, very properly, you add, on the 176th page, fifth line from the bottom: "It would be quite as easy, and the argument could thereby be made quite as strong, to commence with any other bureau"—that is to say, any other bureau than the Geological Survey—"and show its relation to the rest."

A. Yes, sir.

Q. That, as I understand it, simply means that the correlation of the natural sciences is now fully established, and that, wherever you start, you can show that the particular point from which you start must be supported and brought into correlation with the sister branches or sister sciences; for example, instead of saying that geology comprehends more than any other science, physical geography might come in with the same claim for itself. One might say that physical geography included more than any other science, and he might proceed to sweep in your geology as one of his bantlings, and to make topography, altitudes, &c., peculiarly the province of physical geography. I only introduce this to bring forward a point which immediately concerns the Commission.

Suppose this Commission had arbitrary power to do exactly as it pleased, I think it plain from your report that it could go to either of two extremes. It might take all the branches which deal with the physical science of this Government, including the Astronomical Observatory, the Signal Office, &c., and put them under the Geological Survey; or it might go to the opposite extreme and subdivide all these things much more than they are subdivided now. We might have a Bureau of geology subdivided into one of paleontology, meteorology, &c. Therefore, as you understand it, major, it is a matter with respect to administration, is it not, as to what should be done ultimately with all these things?

A. With regard to the comprehensiveness of scientific research, I think that I am right when I state that no field of investigation has been set off by scientific men which embraces so many lines of investigation as geology. I believe that physical geography is now everywhere recognized as a branch of geology, as much so as is paleontology, lithology, structural geology, dynamic geology, &c.

Allow me to state the principle that guides my judgment in the essential point of your question. In the administration of the Government through its several Departments scientific questions may frequently arise; as, for example, in the War Department, questions relating to gun-metal, and others of the profoundest scientific importance, as the armament of our navies and armies, the armor of vessels, &c. Such a question pertains to the functions of the War and Navy Departments, and could not be properly severed from those Departments, as I understand it.

Again, in the construction of public buildings, important questions arise as to the strength, durability, and suitability of building materials. Such questions could not be relegated to any department that did not have immediate charge of the construction of buildings.

Again, in the construction of light-houses, investigations are necessarily in progress as to the penetration of light and sound through various conditions of atmosphere, and other questions of that kind, as you are aware. They belong to light-house construction, and could not be relegated to another department. I tried in my first statement made to the Commission to draw the line between institutions of that class and institutions such as I have enumerated in my recommendations for the plan. It would not be possible to relegate to a group of co-ordinated scientific bureaus all the questions which arise in the course of the administration of the Government, but to these bureaus could be relegated all of that research which is designed to give information to the people, the bureau whose function it is, not to construct works, but, like the Signal Service, to furnish needed information to the people. I should draw the line there.

Q. Between bureaus of construction and bureaus of investigation and information?

A. Yes, sir.

I should say further, that all the Government institutions for investigation and information should be brought under one general management, in order that they might properly assist one another. The work of every one would thereby be stronger and better, and there would be no possibility of duplication. May I continue that statement just a little further? This question has often been raised by statesmen in this country and in Europe: To what extent should the Government assume to do scientific work? In the main I have tried to answer that in the statements previously made. There is one particular principle which I think is recognized by scientific men and statesmen in this connection of very fundamental character. It is that it is not possible for the Government or for individuals to monopolize scientific work, because of its peculiar character. If the people in their corporate capacity engage in the business of the common carrier, to the extent that they do engage in that business the people in their individual capacity are excluded from it. For example, if the people in their corporate capacity carry the mails, then the people in their individual capacity do not carry the mails. If the Government does the express work, then the people do not do the express work. If the Government should do all the transportation for the people, then the people in their individual capacity would not do it. But in regard to research, there is no such limited amount of business. The unknown for which investigators seek is practically infinite.

The CHAIRMAN. There is no monopoly?

Major POWELL. No, sir. The Government does not exclude individuals from the field in any manner, but the Government simply stimulates and assists individuals, and whenever the Government does any of this work, instead of withdrawing other workers from the field, it singularly multiplies the other workers in the field, for science feeds upon itself and grows, while other food is its poison. When a new agency is established for scientific research, it in no manner weakens other existing agencies, but in fact strengthens them. If nine equal agencies are at work the establishment of the tenth agency not only increases the amount of work done to that extent but renders such assistance to all the others that all are more prosperous and more successful. Increase by addition of scientific agencies for research multiplies the product of research. I think that principle is very well recognized by scientific men and by statesmen; so that this does not involve the question of monopoly by the Government in any manner, but aid to the people in systematizing the work, and in doing such work as they cannot do for themselves.

Mr. LYMAN. And you in your excellent statement, which I have read with care, draw the line between the Government work and the individual work, in a general manner, at the point where the work seems to be for the general welfare? Beyond that point you relegate it to private investigators?

Major POWELL. I would not like to state it quite in that way. There is no scientific research which is not for the general welfare. I would rather draw it at the point where private individuals and institutions cannot do the work. At any rate the Government should not perform any work of this character which the people themselves can do in their private capacities, as long as it is neglecting so much which cannot be done by the people, but only by Government agencies. Private research is very greatly retarded in America because certain lines of research which only the Government itself can pursue have been largely neglected. All local geologic work and all local natural history work would be greatly stimulated could there be produced at once a good geologic map of the United States with the topography complete and accurate. Local research could then be much more efficient, and investigators would rapidly multiply.

The CHAIRMAN. You regard this Signal Service work, for example, as Government work, then?

Major POWELL. Yes, sir; that could not be performed by any other agency.

Q. You regard your Geological Survey as practically in the same category?

A. Yes, sir.

Q. As would be the Geodetic Survey?

A. And the Geodetic Survey.

Q. And the Coast Survey?

A. And the Coast Survey.

Q. Are any of these scientific investigations now pursued by the Government such as could as well be done by individuals?

A. No, sir; I think not. I do not know of anything which the Government has undertaken that could be undertaken properly by individuals. The truth is, in my judgment, that no officer of the Government could sustain himself in doing work that private individuals could as well do. The opinion of the scientific public is such that he could not be sustained in doing any work of that character. This is a question discussed very widely among scientific men.

Q. Then there is a substantial concurrence of opinion among the scientific men in favor of the Government doing the work that it is now doing?

A. I think there is.

Adjourned.

WASHINGTON, D. C., *January* 2, 1885.

The Joint Commission met pursuant to call of the chairman. Present, Messrs. Allison (chairman), Hale, Pendleton, Herbert, and Lyman.

Maj. J. W. Powell, Director of the Geological Survey, appeared, having prepared replies to two letters of inquiry addressed to him by the chairman of the commission.

The CHAIRMAN. At the suggestion of a gentleman of the committee I addressed some inquiries to Major Powell a few days ago, and the answers are now here. One of the inquiries was in language which I will read. [Reading:]

SENATE OF THE UNITED STATES,
ROOM OF THE COMMITTEE OF APPROPRIATIONS,
Washington, D. C., December 27, 1884.

DEAR SIR: We see by the Blue Book that there are six men who, as geologists or paleontologists, draw a salary of $4,000 each. The Commission would like to know whether these gentlemen devote their whole time to the work for which they draw salaries, and, if not, how much of their time is so devoted and what other employment or occupation these gentlemen have; and also whether fossil collections, &c., gathered are in the National Museum, or if any other portion of these are in other places or colleges.

We also note that you have a general assistant, at a salary of $3,000. What are his scientific duties with reference to the work?

Yours, truly,

W. B. ALLISON,
Chairman.

Maj. J. W. POWELL,
Director Geological Survey.

Now we have a very full answer to these questions. Shall we have it read this morning?

By general consent the reply of Major Powell was read by the clerk of the committee, as follows:

Hon. W. B. ALLISON,
Chairman Committee of Commissions:

SIR: In reply to your interrogatories I have the honor to make the following statement:

The five geologists to whom reference is made are Messrs. S. F. Emmons, G. K. Gilbert, Arnold Hague, F. V. Hayden, and G. F. Becker. Each of these gentlemen receives a salary of $4,000 per year, and each one devotes his whole time to the work of the Geological Survey; and each one is in charge of an important division, with a corps of assistants under him. Prof. O. C. Marsh is the paleontologist receiving a salary of $4,000. He also devotes his entire time to the work of the Geological Survey, and has a corps of assistants working under his direction.

In the case of those persons who are employed on the Geological Survey for special services, and whose time is not wholly given to the work in the Survey, their services are usually paid for by the day; in some few cases by the month. The vouchers for these payments are accompanied by the certified statements of the chiefs of the divisions under which the services are rendered, and the whole is checked by the monthly report of operations. This report is received from every party, in the office and in the field, engaged in work under the Geological Survey.

There is much work in the operations of the Geological Survey of a peculiarly technical character that must necessarily be performed by experts, and it is the policy of the Survey to employ the highest expert talent of the country on this work. Thus, for example, the following persons have been employed during the first six months of the present fiscal year, and have been paid the amounts set opposite their names for services and traveling expenses.

In compliance with Treasury regulations, persons employed by the month are rated by annual salaries, as months are of unequal length:

	Amounts paid during fiscal year ending June 30, 1885.
Chauvenet, William M., analytic and consulting chemist, Saint Louis, Mo.; at the rate of $5 per day	$210 00
Daniels, W. W.; $5 per day	125 00
Davis, William M., instructor in geology at Harvard University; $5 per day	000 00
Fontaine, William M., professor of geology at the University of Virginia; $2,000 per annum	910 46
Hall, C. W., instructor in geology, mineralogy, zoology, and botany, in the University of Minnesota; $4.50 per day	279 00
Newberry, John S., professor of geology, School of Mines, Columbia College, New York; $3,600 per annum	596 70
Pritchett, H. S., director observatory, Washington University, Saint Louis.	000 00
Safford, J. M., state geologist, Tennessee; $1,800 per annum	000 00
Shaler, N. S., professor of geology, Harvard University	203 00
Salisbury, Rollin D., professor of geology, Beloit (Wis.) College; $5 per day	240 00
Stone, George H.; $5 per day	260 00
Whitfield, R. P., curator of paleontology, American Museum of Natural History, New York; by the piece	1,040 00
Williams, H. S., professor of paleontology, Cornell University; $1,500 per annum	373 60
Wright, George F., professor of geology, Oberlin College; $5 per day	300 00
Dana, E. S., professor of mineralogy in Yale College	150 00

In addition to those named in the above list, the following persons are now in the employ of the Geological Survey doing the work of specialists, and will receive for their services sums varying from $25 to $300, by special contract: Dr. R. W. Raymond, formerly United States mining commissioner; Mr. James M. Swank, secretary of the American Iron and Steel Association; Mr. John Birkinbine, secretary of the Association of Charcoal Iron Workers; Dr. H. M. Chance, second Geological Survey of Pennsylvania; Prof. C. A. Ashburner, second Geological Survey of Pennsylvania; Prof. Andrew McCreath, of Harrisburg, Pa.; Prof. E. W. Hilgard, University of California; Prof. F. A. Wilber, Rutgers College; Mr. Malvern Iles, Omaha and Grant Smelting Works; Prof. W. C. Stubbs, State chemist, of Alabama; Prof. E. A. Smith, State Geologist, of Alabama; Prof. William L. Dudley, of Cincinnati; Mr. William Martyn, of Charlestown, Mass.; Dr. Edward Peters, Parrot Copper Company; Mr. H. M. Howe, metallurgist, Boston; Mr. H. O. Hofman, metallurgist, Kansas City, Mo.; Mr. W. S. Jarboe, Natural-Gas Works, Pittsburgh; Mr. Charles Kirchhoff, jr., editor Mining and Engineering Journal, New York; Mr. C. C. Yale, editor Mining and Scientific Press, San Francisco; Mr. F. F. Chisolm; mining engineer of the Union Pacific Railroad Company; Mr. S. H. Stowell, Pittsburgh, Pa.; Mr. S. C. Armstrong, Pittsburgh, Pa.; Mr. Joseph Weeks, Pittsburgh, Pa.; Prof. W. P. Blake, New Haven, Conn.; Mr. P. Barnes, metallurgist, Westfield, N. J.; Mr. G. F. Kunz, mineralogist; Mr. H. G. Hanks, State mineralogist of California; Dr. Henry De Groot, mining engineer, San Francisco; Dr. William Bredemeyer, mining engineer, Salt Lake City; Dr. David T. Day, Baltimore; Prof. J. C. Smock, Rutgers College; Mr. D. B. Huntley, superintendent Grand Central Mill, Tombstone; Mr. J. A. Walker, secretary Dixon Crucible Company, Jersey City; Mr. Stuart M. Buck, Coalburg, W. Va.; Dr. O. A. Moses, New York; Mr. F. E. Saward, editor Coal Trade Journal, New York; Mr. F. L. Clerc, metallurgist, Philipsburg, Pa.; Mr. A. P. Swineford, Marquette, Mich.; Dr. O. H. Hahn, Pueblo, Colo.

Still, in addition to this, more than 2,000 persons, correspondents of the Survey, are doing important work in reporting observations and making collections of statistics and material, who receive no compensation therefor.

In reply to your interrogatory relating to the general assistant, I beg leave to state that practically there are two such assistants in the Survey, but designated by different titles—one as "executive officer" and the other as "general assistant." These two officers perform duties analogous to those of quartermaster and commissary of subsistence; that is, they purchase and take general charge of transportation and supplies to parties in the field. The Geological Survey must necessarily have many horses, mules, wagons, harnesses, &c., and the parties in the field must be supplied with rations; instruments, collections, &c., have to be transported from one point to another. A great variety of duties of this character arise to be performed by these two officers, one of whom operates in the West, beyond the Mississippi River, the other on the eastern side of the Mississippi River; but their general duties are the same. Mr. James Stevenson, whose field of work is in the West, in addition to his general duties, makes large collections of various kinds. Mr. George Shutt, who is the general assistant for the eastern portion of the United States, has general charge of the forestry work.

In reply to your interrogatory in relation to the place of deposit of the collections, I have to state that the law specifically provides that the collections of the Geological Survey shall ultimately be placed in the National Museum; but while such collections are under immediate study they must necessarily be in the hands of the scientific men who are making the special studies. While, therefore, the National Museum is the general depository for the collections, special collections are for short periods of time withheld from the general collection, and from time to time withdrawn therefrom. Some of the collections in this condition are in the building occupied by the Geological Survey in F street, and others are scattered in various portions of the United States in the hands of specialists. For example, certain fossil plants are in the hands of Professor Fontaine, at the University of Virginia; certain fossil plants of another geologic age are in the hands of Professor Newberry, at Columbia College; certain fossils, minerals, and rocks are in the hands of Professor Shaler, at Harvard University, &c.

Again, the Geological Survey has never had sufficient office and laboratory room in Washington to supply its wants, and has not at the present time; under the law it is not possible to rent additional rooms in Washington, and the Director of the Survey has been very anxious not to pay rents outside of Washington where it could possibly be avoided. Under these circumstances rooms for the Geological Survey have been secured in the customs building in San Francisco. At the present time rooms are rented in Denver, but it is expected that on the completion of the new Government building in Denver rooms will be reserved for the Geological Survey; collections are also kept in San Francisco and Denver. Again, various educational and scientific institutions of the country have come to the assistance of the Survey in this matter. Thus, the trustees of the American Museum in New York City have given to the Geological Survey, rent free, a suite of furnished, heated, and lighted rooms in their building, in which that division of the Geological Survey over which Mr. Hague has charge has been quartered until the present month; the additional room granted by the last Congress, in the authority for renting the building in F street, renders it possible to withdraw the force from New York to Washington, and in so doing the collections previously kept at that point have been shipped to Washington. In like manner Yale College has given to the Survey, without cost, a large number of rooms for the laboratory of vertebrate paleontology, for the accommodation of the collections made by Professor Marsh and his assistants. It is not possible yet to remove this laboratory with its collections to Washington, for at least twenty more large rooms, with laboratory appliances, must be provided for their accommodation. No additional space can be had in the National Museum, and there is not room in the present building occupied by the Geological Survey; and it would be unwise to incur the expense of providing and preparing paleontologic laboratories in a rented building. Again, the University of Wisconsin furnishes to the Geological Survey laboratory room in the same manner as does Yale College. This is chiefly for chemic researches; but, through the courtesy of Professor Baird, the Geological Survey is enabled to have a laboratory sufficient for this purpose in the National Museum, and the chemic work will be removed this winter from Madison to Washington.

The State of Massachusetts and the State of New Jersey each furnishes office room for employés of the Geological Survey.

It will be seen that the collections of the Geological Survey are in small part in the hands of specialists scattered throughout the United States, and in small part in the various rooms occupied by members of the Survey scattered about the United States, but the major part of these collections is in the National Museum.

The statute relating to the custody of collections is as follows:

"And all the collections of rocks, minerals, soils, fossils, and objects of natural history, archæology, and ethnology, made by the Coast and Interior Survey, the Geological Survey, or by any other parties for the Government of the United States, when no longer needed for investigations in progress, shall be deposited in the National Museum."

It will be seen that the law contemplates that all collections shall ultimately go to the National Museum, and, further, that when the investigations are in progress such collections may be held elsewhere.

J. W. POWELL,
Director.

By Mr. HERBERT:

Q. Major, what are you doing now in ethnology?

A. The ethnologic work of which I have charge is not a part of the work of the Geological Survey, but a part of the work of the Smithsonian Institution. For some time I was connected with the Smithsonian Institution in charge of that work. When I was appointed Director of the Geological Survey, the Institution still gave me the general direction of the ethnologic work, so that I now practically report to two chiefs, one being the Secretary of the Interior and the other the Secretary of the Smithsonian Institution. I report to the Secretary of the Smithsonian Institution on the operations of ethnologic researches. There is a practical advantage in my having charge of that work as Director of the Geological Survey, because the work is scattered throughout the United States, and parties traveling throughout the country in prosecuting the geologic work can also do a part of ethnologic work. It can be done more economically in conjunction with the work of the Geological Survey than in any other way.

Q. Are the expenses of the ethnological researches paid for by the moneys of the Smithsonian Institution?

A. They are paid from specific appropriations made by Congress for that work under the direction of the Smithsonian Institution.

Q. But they are separate and distinct from the geological work?

A. Yes, sir; and the estimates for it are made by the Secretary of the Smithsonian Institution.

By Mr. HALE:

Q. You keep separate accounts of them?

A. Yes sir.

By the CHAIRMAN:

Q. Here is the item of appropriation for that purpose [reading]:

> For the purpose of continuing ethnological researches among the American Indians, under the direction of the Secretary of the Smithsonian Institution, including salaries and compensation of all necessary employés, forty thousand dollars.

That, I suppose, is the way the appropriation runs from year to year?

A. Yes, sir; that has been the amount for the past two or three years.

By Mr. HERBERT:

Q. Is that work done by the same force or by part of the same force that you have prosecuting the work of the geological survey?

A. In part by the same force and in part by a distinct corps of experts. To understand that properly it will be necessary for me to give an outline of the work: First, we are preparing an Indian atlas of the United States in two parts; the first part will exhibit all the cessions of lands by Indian tribes to the United States—in all parts of the United States, and all reservations of lands for the Indians, together with specific grants of lands to Indians where it has been intended that they should receive lands in severalty. The second part of the atlas is designed to show the original distribution of the Indians in the United States.

By Mr. LYMAN:

Q. At the time when the white man arrived?

A. Yes, sir; when they were first discovered by white men. Such is the first part of the work. The second part is the linguistic classification of the Indians of North America. More than five hundred distinct languages are spoken in North America, and linguistic differences among tribes lead to many complications in the administration of Indian affairs, and many important questions have arisen therefrom. The Indians who speak languages of the same stock have common traditions, common mythologies, common religions, &c., and are classed together. They are usually friends, or can be made friends and brought together under one administration, while Indians belonging to distinct linguistic stocks have distinct traditions, mythologies, and religions, and consider themselves distinct peoples, and are often hereditary enemies. Such feelings are much stronger in savage races than amongst civilized peoples. In the administration of Indian affairs many difficulties arose from this condition of things, and finally the question of the classification of the Indians became desirable. When General Walker, the Superintendent of the Tenth Census, was Commissioner of Indian Affairs, he asked that a classification of the Indians by their linguistic affinities might be made. Subsequently, under instructions from the Secretary of the Interior, that work was undertaken by myself as the director of the Survey of the Rocky Mountain region. When the various surveys were consolidated some years ago, this particular work was relegated to the Smithsonian Institution and conducted by myself. When, afterwards, I was appointed Director of the United States Geological Survey the control of the work was left in my hands. In connection with the linguistic researches much is done in studying the institutions of the Indians, that is, the customary laws by which savage society is regulated relating to marriage customs, personal relations, property customs, crimes, &c. The governmental organization of the tribes also is investigated. We also conduct extensive researches relating to the mythologies and religions of the people—all in connection with the study of the languages, and as part of that study.

The third part of the work relates to the study of the arts of the Indians, arts relating to house-building, domestic life, hunting, fishing, &c. I mean by this, the arts of the present tribes which they have practiced since the advent of the white man. The fourth part of the work relates to the antiquities of the country, the study of mounds, the study of caves at one time occupied by man, ancient village sites, and especially the ruins found scattered so profusely through the southwestern portion of the United States. This study of the antiquities will ultimately result in the preparation of an archæologic atlas of the United States, with descriptive text.

The ethnologic corps prosecuting the researches is in the main distinct. The philologists are paid from the appropriation for ethnology. All of these persons who explore mounds, cliff-dwellings, ruins, and other prehistoric remains have their expenses paid from the ethnologic fund. The clerical work in my office, however, is done by clerks of the Geological Survey. For instance, the disbursing of moneys is done by the disbursing clerk of the Geological Survey in addition to his other duties and without other compensation. The correspondence which arises, and which is very great, embracing many hundreds of people scattered throughout the United States, is, so far as clerical work is concerned, conducted by the clerical force of the Geological Survey. The salaries of specialists and their field expenses are paid from the ethnologic fund.

There is yet another connection between the geologic and ethnologic work. The Geological Survey is constructing a topographic map of the United States, and in doing this work the topographers in the field place upon the field sheets the mounds, ruins, and other archæologic data discovered by them These items do not finally go upon the engraved sheets to any great extent, but are collected in the office by the ethnologists, to be ultimately placed upon the archæologic map. This part of the work done by the topographers can be accomplished with very little additional expense, as they must necessarily go over the country in the prosecution of their regular work. Some of the items are of sufficient importance to be placed upon the topographic maps themselves. Again, as facts of this character are discovered by topographers and by the geologists they are reported to the office, and more minute examinations are then often made by the ethnologists. Again, the geologists themselves in the prosecution of their work also collect many facts relating to ethnology, and turn over such material to the Bureau of Ethnology.

To some extent the persons engaged in ethnologic work, especially in the far West, travel with the geologic parties, and a saving of expense results therefrom. In this connection it may be stated that a large part of the expense of transportation in this work, as well as in the geologic work, is saved through the courtesy of railroad companies—many railroad and express companies transporting material without charge.

By the CHAIRMAN:

Q. Do you refer to the personnel or material that is carried?

A. Both. Mr. Stevenson, the general assistant of the Geological Survey, has secured in the West several thousand dollars' worth of free transportation during the past year, and in like manner has saved much money to the work for many years. Mr. Shutt has also saved several thousand dollars in procuring free transportation in the East.

By Mr. HALE:

Q. What stage of progress has this eastern part of the work reached?

A. That part relating to cessions of land and reservations will be complete in a few months, but the remaining portion will take years. The part which I hope to have ready in a few months is much needed in the Indian Bureau and by various persons throughout the country. I have frequent calls for information involving questions being investigated by the Bureau of Ethnology—questions touching precinct, county, and State lines, which sometimes rest upon old treaties with the Indians. Old treaty lines have been taken as boundary lines, and sometimes the officers of courts apply to the Bureau of Ethnology for information upon such matters. Altogether there is a pressing necessity for this work, and we are trying to complete it at an early day.

Q. That takes in all the country except Alaska, does it?

A. Yes, sir; but the classification of languages includes Alaska and all of North America.

Q. Do you mean the linguistic classification?

A. Yes, sir.

Q. Including the native tribes of the Pacific coast?

A. Yes, sir.

By Mr. HERBERT:

Q. Have these archæologic researches of which you have spoken as made by you resulted in the change of any county lines, or of any State lines anywhere?

A. I do not know. That is a delicate question. I try to avoid being placed in an antagonistic position to any parties in controversy. I simply furnish historical facts that are needed; for example, that in such and such treaties such and such lines are described, and where these lines are.

Q. You state that these cessions of these lands occupied by the Indians of these different territories have an important bearing upon the State and county lines, and the point of my inquiry is, have the courts anywhere recognized and acted upon the result of your researches to the extent of declaring any change of any county lines or of any boundary lines anywhere in the United States that you know of?

A. I do not know. I have not followed the history of these affairs to their outcome.

By Mr. HALE:

Q. How many ethnologic reports have you made, Professor Powell?

A. Four.

Q. Four volumes of reports?

A. Yes, sir.

Q. For what years, respectively?

A. The first report was for the fiscal year 1879–'80, the second for 1880–'81, the third for 1881–'82, and the fourth was for 1882–'83. The fifth, for 1883–'84, has been ordered by Congress, and is nearly ready for the printer. The first and second reports are printed and have been distributed. The third and fourth are in the hands of the printer. These are the annual reports of the operations of the Bureau, and to them are appended important scientific papers. In addition to this, there are certain monographs or quarto reports relating to the languages of the Indians, their arts, and other matters. The printing of ten of these volumes has been ordered by Congress. Four of them, numbers 1, 3, 4, and 5, are issued, numbers 2, 6, and 7 are partly printed, and numbers 8, 9, and 10 are in course of preparation in the office. These volumes contain materials collected by myself when in charge of the survey of the Rocky Mountain Region, materials subsequently collected by the Bureau of Ethnology prior to my appointment as Director of the United States Geological Survey, together with materials collected since that time.

Q. From what year do these reports run?

A. From 1877.

By Mr. HERBERT:

Q. In what portion of the territory of the United States have these archæologic and linguistic researches been completed?

A. They are incomplete everywhere. When complete in one region they will be complete for all regions. In the main they cannot be completed by districts; as, for example, the great family of Dakota Indians, stretching throughout the northern portion of the valley of the Mississippi and Missouri, is one of the most consolidated families with which we have to deal, but one of the tribes of South Carolina belongs to this stock. Then the Apaches and Navajoes who live in the southwestern portion of the United States are connected with the tribes of California and Oregon by language, while the main seat of that stock is the region of Lake Athabasca, in British America. Hence, the Indians of the United States belonging to this stock are invaders from British America. The Apaches and Navajoes extended their migrations southward into the region of country occupied by the pueblo builders—a more sedentary people. The northern invaders came into that country as enemies—perhaps for the purpose of plunder—but finally settled there, and these Athabascan tribes are now the hereditary enemies of the pueblo Indians. But I am going too far in this matter and wandering from a proper answer to your question. As my illustration shows, many of the stocks are widely scattered. The point to which I wish to call your attention is that in the execution of this work it is necessary to take in all the country before a *complete* classification can be accomplished, but a *tentative* classification has already been made.

By the CHAIRMAN:

Q. Has not Bancroft gone into that classification pretty thoroughly?

A. No, sir; not very thoroughly.

Q. Does he not undertake to account for the origin of tribes, &c.?

A. No, sir. The linguistic classification of the people is not undertaken by Bancroft in his great work upon the Tribes of the Pacific Coast. He simply classifies them geographically.

By Mr. HERBERT:

Q. Major, in how many instances has your investigation of the five hundred languages been completed?

A. Well, that is a difficult question to answer—that is, to state that any investigation in this line is complete. A tentative or preliminary classification has been made by myself and is now in manuscript form, and a map of the United States has been constructed and hangs in my office showing the distribution of the linguistic stocks which I now recognize, over the larger portion of the United States; but new questions arise from time to time, new facts are coming in, and the present classification is therefore far from being final.

Q. How long would it take, according to your present plan of proceeding—supposing the appropriations to be annually what they are now—to complete this archæologic and linguistic investigation?

A. I could make a pretty good final report in, say, ten or twelve years, but the work could and should be carried on to a much greater degree of thoroughness.

Q. Then after that is completed you might go on to a more thorough investigation and continue it almost *ad infinitum*?

A. Yes, sir.

By Mr. HALE:

Q. Do these five hundred languages include all those in North America?

A. Yes, sir; speaking in general terms, it is probable that there are more than five hundred, grouped in more than sixty stocks, as based upon present knowledge.

By Mr. LYMAN:

Q. When you use the word "language," you include what in Europe they call the "patois"?

A. Oh, no, sir; not that.

By Mr. HALE:

Q. What do you mean by the sixty stocks of languages?

A. A linguistic stock is a group of languages—few or many, as the case may be—having such relation to one another that they are probably descended from a common language spoken in some ancient time. The stocks are completely distinct from one another; as distinct, for instance, as Aryan, Chinese, and Semitic. There is no evidence that they have ever been one.

Q. And by the five hundred you have reference to dialects?

A. I mean five hundred languages that are not intelligible to other tribes that do not speak them. Not dialects wherein there are slight variations, as the dialects of the English language as spoken in England, but languages that differ from each other as do French, English, and German. A number of languages thus differing are grouped into one stock, because upon ultimate analysis they exhibit the fact that they have common roots. It is probable that the number of stocks will be increased by future investigation, but it may be that the number will be diminished.

Q. That work ought to be a very interesting one.

A. I think there are no publications made under my direction that have so wide an interest. Much of the material, in one form or another, is translated into most of the civilized languages of the world.

By the CHAIRMAN:

Q. Are there any specific number of those works published?

A. Of the first monograph 2,000 copies were ordered; of the second, 3,000 copies; of the third, 2,000 copies; of the fourth and fifth, 5,000 copies each; and of the sixth, seventh, eighth, ninth, and tenth, 6,000 copies each. Of the annual reports there were ordered 15,000 copies of each of the first, second, and third, and 15,500 each of the fourth and fifth. In addition to the numbers given there are also printed 1,900 copies by general law.

By Mr. HALE:

Q. That is, they are published every year and distributed through Congress?

A. Yes, sir.

By the CHAIRMAN:

Q. They are exhausted, of course, very rapidly?

A. Yes, sir.

By Mr. LYMAN:

Q. I noticed, major, in your list of employés, two specialists with whom I am well acquainted, Mr. Davis and Professor Shaler, of Harvard College. They, as I understand, are employed as experts, and simply do a little work outside of their duties there, and are paid for it?

A. Yes, sir.

Q. Then I do not quite understand about the professor of paleontology. Does he hold a professorship like these gentlemen I have just described?

A. No, sir. He holds an honorary position in Yale College, as I have myself in a college in Illinois, but he performs no functions there as a teacher or lecturer and receives no salary there. He devotes his entire time to paleontologic research—making collections in the field and preparing reports upon the same in the office. I may add that many of the employés of the Geological Survey have honorary professorships in different institutions.

Q. Professor Marsh gives his whole time to you?

A. Yes, sir; and would probably be in Washington if I could give him room and facilities for his work.

The CHAIRMAN. I submitted to Major Powell another inquiry more on my own account, perhaps, than for the information of the Commission, and yet the answer seems to go into matters quite in detail. I will read my letter to the major [reading]:

SENATE OF THE UNITED STATES,
ROOM OF THE COMMITTEE ON APPROPRIATIONS,
Washington, December 26, 1884.

DEAR SIR: In examining with care your last statement in response to the letter of the Commission addressed to the Secretary of the Interior, we find that you say that you have elsewhere described the methods in use by your survey in making topographic surveys, and you state that these methods differ from those in use by the Coast Survey. On examining your testimony I fail to find any description in detail of your topographic methods as distinguished from those of the Coast Survey. I will thank you to send to the committee a statement of your plan of making topographic surveys, and wherein it differs from the Coast Survey methods, as to the accuracy and economy, as, also, the utility in use; or if this has already been done, will you kindly refer me to the page of your testimony which contains such statement.

What we want, really, is a statement of your topographic methods as compared with those of the Coast Survey.

Very truly yours,

W. B. ALLISON,
Chairman.

Maj. J. W. POWELL,
Director Geological Survey.

Mr. PENDLETON. I suggest that the reply be read.

The clerk was directed to read.

MAJOR POWELL. Mr. Chairman, I fear the clerk will find it somewhat difficult to read, in consequence of interlineations resulting from the haste with which I was compelled to prepare the statement in order to reach you with it in time for your meeting this morning.

The CHAIRMAN. We would prefer that you read it yourself, major, if agreeable to you.

Major POWELL then read his statement as follows:

In reply to the foregoing inquiries, I beg leave to make the following statement:

As understood by myself, four questions are involved, viz:

I. What are the purposes to be subserved by the maps made by the Coast and Geodetic Survey and Geological Survey, and how do they differ in purpose?

II. What are the methods of making surveys and maps in the two organizations, and how do they differ from each other?

III. What is the degree of accuracy reached in making maps by the two organizations, and how does this accuracy compare?

IV. What is the cost of making maps by the two organizations, and how do these costs compare?

I have put the questions in this order for convenient reply. The answers to the above interrogatories are in large part contained in my former statements to the committee, but not in full, and not in detail; and by reason of the interlocutory form of my statements the answers are not properly connected. The following statement, I believe, will make a more connected and complete answer:

I. *With regard to the purposes of the maps made by the two organizations.*

The Coast and Geodetic Survey constructs maps, or, more properly speaking, charts, of the coast. These charts represent in part water areas, and in part land areas. On the water areas are represented the soundings and important features of the sea and river bottoms. Other thing also are represented, such as buoys, lights, &c. The land areas rep ed are in part islands, and in part mainland. On these land areas [illegible] presented the landmarks which are used by mariners in the navigation of the waters. So far they are strictly coast charts, useful in navigation.

In surveying the land areas, the Coast Survey does something more by extending the map work back a short distance into the country, varying from half a mile to 5 miles. This additional work is of a peculiar character. All streams, large and small, that run in or through this margin of land, are plotted upon maps; all coast marshes are plotted; all rocky ledges and points are indicated, and to some extent, hills are represented. In addition to this, many artificial features are plotted, such as city, town, and village plats, country roads, farms, fields, houses, and many other artificial or cultural details. The surveys made for these cultural details do not include complete cadastral surveys, but only sufficient cadastral surveying to make it possible to correctly plot such items upon the maps. I am unable to state any useful purpose which this cadastral or artificial element in the coast charts subserves; first, because it is not executed so as to form a complete cadastral map; second, because these artificial topographic features are ephemeral; that is, this culture changes from year to year in such a manner that the charts speedily become misleading. In illustration of this fact I may state that one of the commissioners of the Massachusetts survey informs me that he has lately examined certain charts made in Massachusetts on this plan, and he discovers that in the areas coming under his eye 50 per cent. of the houses placed upon the chart twenty years ago have disappeared, or been removed to new sites; that in addition to this a large number of new houses have been erected which do not appear on the old charts, and that the confusion arising from these two causes renders the charts almost unintelligible. He also informs me that the same confusion arises from the delineation of fences, but to a greater extent, and that a similar confusion arises through the delineation of minor public or private roads, but not to so great an extent.

Topographic maps made by the Geological Survey have for their purpose the representation of natural features of the country, such as all streams and bodies of water, all valleys with their undulations, all hills and all mountains. In addition to this, certain cultural features are added. These are all important highways, as canals, railroads, and wagon-roads, the sites of all cities, towns, villages, and railway stations.

The purposes to be served by such topographic maps are very many.

First. They are used as geologic maps on which to represent, by conventional colors and characters, geologic formations. This is the immediate purpose for which the maps are constructed by the Survey.

Second. As the altitudes of all portions of the country are determined, they can be used for the purposes of the Signal Service.

Third. They subserve all the purposes of military maps as demanded by modern military science, except that they are not on a sufficiently large scale to be of avail for battle maps in reporting the details of a conflict after it has occurred. Such maps can be constructed only after battles have been fought.

Fourth. The maps serve a valuable purpose to cities and towns in securing a proper supply of water. The maps being constructed with grade curves, every elevation and depression is represented with mathematic accuracy, and the maps can be used in laying out the course of aqueducts for the purpose of bringing water from distant rivers, springs, or lakes, to the towns and cities where it is needed. While the general route for such aqueducts can be planned from these maps, the lines themselves must eventually be surveyed and marked upon the ground, and the data collected for construction. Again, the source of water supply for any town and city is the rain which falls upon some large district, and which is gathered into a stream or lake by natural agencies before it is conducted by art to the place where it is needed. These catchment areas are of great interest to the people who use the water therein gathered, as they must be protected so that the waters may not be corrupted by foul and pestilential agencies. Thus the topographic maps prepared by the Geological Survey supply a want felt by city engineers and other municipal authorities in planning and protecting water works.

Fifth. As the topographic maps of the Geological Survey are constructed with grade curves, so as to show the relative levels of all portions of the country to each other and to the level of mean tide, they can be used in determining the possibility and practicability of draining all marsh lands on the coast, and all interior swamp lands.

Sixth. They subserve valuable purposes to the people in the planning and laying out of highways, such as wagon-roads, canals, and railroads. With such maps constructed, all preliminary railroad surveys become unnecessary, and every citizen has at his command a map on which railroad routes can be planned; but final surveys for railroads are still necessary for the purpose of marking the lines upon the ground and collecting the data for construction.

Seventh. The topographic maps of the Geological Survey, in conjunction with geologic maps, are used for determining the sites of artesian wells. Artesian waters have come to be of great importance in the United States. Along the eastern shore, especially in New Jersey, and in Wisconsin, Illinois, and elsewhere in the eastern portion of the United States, and everywhere throughout the arid regions of the West, a supply of artesian water is one of the great needs. The people are calling for information upon this subject, and the Geological Survey is supplying a practical want in this direction.

Eighth. In about two-fifths of the whole area of the United States, exclusive of Alaska, agriculture is dependent upon artificial irrigation. In all of these regions the streams have to be conducted from their natural channels by canals, and spread over the surface of the earth to fertilize the soil. In all of this area topographic maps are of the highest importance, and subserve an immediate and practical want. In illustration it may be said that every town in Utah has been moved, perhaps twice on an average, after it has been built, by reason of errors in selecting sites.

Mr. LYMAN. By reason of errors in reference to altitude?

Major POWELL. For various topographic reasons, chiefly relating to altitude. Towns have been planted and they have subsequently found that the water could not be economically brought to them or could not be economically controlled, and it has been found to be better to move the towns than to incur extraordinary expense in water works.

I beg to be permitted to make the following statement in this connection. The studies which I have made of topographic methods and of the economics of topographic surveys grew out of my interests in these arid lands, for I found in traveling through that region that the people were in quest of some economic but simple and practical means of learning how the streams of that country could be utilized; and I found that many millions of dollars had been wasted in experiments on irrigation, by reason of the lack of proper topographic information.

Ninth. One of the most important problems presented to economic engineers, and especially employed by the General Government, relates to the control of great rivers. All rivers have, to a greater or less extent, broad flood-plains—districts of country which are annually or occasionally inundated; and by these inundations property of great value is destroyed. For the solution of these problems the primary necessity is a topographic map, and without it the first steps cannot be taken. A topographic map of the United States, therefore, has a high value in furnishing the necessary data to engineers in making plans for the protection of flood-plains. To illustrate this subject I beg to call the attention of the Commission to the great valley of the Lower Mississippi, extending from Cairo to the mouth of the river. This flood-plain, could it be properly protected from inundation, would be one of the most fertile districts in the United States, on which corn, cotton, and sugar could be produced in vast quantities. The topographic map now in process of construction by the Geological Survey will be of great value in the solution of this problem. Already sufficient facts have been collected to clearly show how the problem is to be solved. The great floods of the Lower Mississippi have their chief origin, though not their whole origin, in the Missouri River and its western tributaties, and the floods of these streams come from the melting of the snow in the Rocky Mountains. Now these snows melt in the spring and early summer time, and the waters which result therefrom can be taken out of their natural channels and poured upon the great arid plains, and used in the irrigation of lands that are now practically deserts. The relief thus afforded to the lower valley of the Mississippi at flood time would, in large part, redeem these valuable lands, and at the same time, for every acre of corn, cotton, and sugar lands redeemed in the lower valley, two acres of wheat lands would be redeemed in the deserts of the north. The interests of those two districts of country are bound together, and the only practical way of redeeming the Mississippi valley is by redeeming the deserts of the great plains. All other methods have proved futile and will prove futile.

A commission in Massachusetts has lately been engaged in the study of the valley of the Connecticut, for the purpose of devising means for the protection of that valley from inundation, and at their request that portion of the valley of the Connecticut that extends through the State of Massachusetts was mapped by the Geological Survey during the past year.

Tenth. Many county and township maps have been made, in part under the direction of the local authorities, and in part by private enterprise. These are essentially cadastral maps, and are designed to represent estates. Such local, county, and township maps, however, usually lack in the element of natural topography. But wherever this natural topography has been delineated by the Government surveys, the maps thus produced are used by the local surveyors, and on them are plotted the cadastral lines and characters; and by this means the local maps are greatly enhanced in value.

Eleventh. One of the most important purposes which such maps subserve is the furnishing of general information to the people as to the characteristics of any district of country of which they may inquire, or in which they may be interested, as they exhibit to the eye in the clearest possible manner all of the natural features of the country, and all the important facts about its elevation above the sea, the extent and character of its valleys, hills, mountains, the course of all streams, the sites of all bodies of standing water, and the geographic location of all cities, towns, and highways.

Twelfth. As these maps are constructed they speedily fall into the hands of map and school-book publishers, and the materials which they contain go into every school of the land—in primary schools in skeleton form only—in the higher schools, colleges, and universities, in more elaborate form. Already the geography of the United States is taught in the schools of this country chiefly from the materials furnished by the Government surveys.

Thirteenth. Topographic maps, such as are constructed by the Geological Survey, serve many important scientific purposes. They are needed by naturalists in studying the habitat and geographic distribution of plants and animals, and by ethnologists in studying the geographic conditions under which the primitive or savage races of the country developed their arts, institutions, and mythologies. They are useful to the archaeologist in studying the position and characteristics of the antiquities of the country, as mounds, ruins, &c.

It is impossible in a reasonable space to set forth all the purposes subserved by the maps made by the Geological Survey. Their utilities are many, and relate directly and indirectly to all the industries of the country. The history of the uses to which maps already made have been put fully demonstrates the statements made above, as the maps now constructed are in fact being used by the people for all of the purposes enumerated. The coast charts of the Coast and Geodetic Survey do not subserve these purposes, because they do not convey the necessary information, being constructed on another plan—for another purpose. The Coast Survey charts subserve the purposes of mariners; the Geological Survey maps subserve the purposes of landsmen. The Coast Survey charts, as they extend inland, chiefly represent cadastral features; the topographic maps of the Geological Survey chiefly represent natural features.

By the CHAIRMAN:

Q. In your testimony somewhere you have stated that this topographic map is completed so far as one-fifth of the United States are concerned?

A. Yes, sir.

Q. That is, of course, the areas of the Territories, the region surveyed by Hayden, yourself, and others?

A. Yes, sir; but work has been done all over the country; we have been working east of late years, you know.

Q. And these surveys include the topographic map as you have explained?

A. Yes, sir. It is proper to say that some of the earlier work done many years ago is not up to the present standard, but we have gone over such work and corrected the little points where it was necessary.

Q. Take for illustration the State of Colorado. I understand that State was surveyed by Hayden?

A. That State was surveyed by Hayden.

Q. Now, have you a topographic map of the State of Colorado substantially such as you have described in your statement?

A. Yes, sir.

Q. The whole of that State?

A. Yes, sir; and the Denver and Rio Grande Railroad laid out its lines by the use of our maps; that is, by the Hayden map in part, and my map in Utah in part.

Q. Are these maps now in such a state of completion as that they delineate the depressions and elevations in the Rocky Mountains?

A. So far as they have been extended.

Q. So far as they have gone over the particular area?

A. Yes, sir.

By Mr. HERBERT:

Q. I have understood, either from you or from Professor Hilgard, that these coast surveys extending into the interior were not utilized in making property maps at all; that the lines of property are determined by the surveys formerly made by the Land Office Department; am I correct or not?

A. The Coast Survey charts do not extend over lands where the Land Office surveys have been made, and the Coast Survey charts are not complete cadastral maps, nor has the Coast Survey made cadastral surveys.

Q. Then, if so, what use is there of making a cadastral map, as you call it?

A. I have discussed that point quite at length in a former statement. The purpose of that survey is not to make cadastral surveys, but to furnish such datum points for counties, cities, towns, &c., as will enable them to do that work for themselves.

Q. But if the lines of counties and the lines of properties are already fixed by their surveys and are not to be unsettled by these interior coast surveys, have these geodetic surveys really any value whatever in the making of cadastral maps?

A. They will have the highest value for that ultimately.

Q. Why ultimately, if the lines are not to be changed?

A. Because the points upon the ground are to be preserved and discovered when inquiry comes up about boundaries. How do they know but that I have changed my landmarks? Controversy may arise between my neighbor and myself, and how are we to know just where the landmark was? At the present time there is no means of preserving those lines against fraud. In all countries where property has come to be of high value they establish geodetic points to which all private surveys are ultimately related, and the state takes charge of the work. The Government in some of its units keeps the custody of these marks or datum points, and property surveys are related thereto.

Q. Then you mean to say when these geodetic points are fixed by this manner, they will be eventually utilized by having the lines of the properties as now laid resurveyed with reference to those points, and until that time they would be entirely useless as cadastral maps?

A. Yes, sir; the datum points cannot be used in property surveys until the people themselves, through local authorities, initiate methods by which local property surveys are related to the datum points. [Resuming his statement.]

II. *As to the methods of survey in the two organizations.*

They agree in part and disagree in part. To set this forth clearly it will be necessary to take up the work by stages somewhat in detail.

(*a*.) In both surveys base-lines are measured. The Coast and Geodetic Survey measures base-lines with two classes of apparatus. The more important bases are measured with an apparatus which is very elaborate and expensive, and much time is required and expense incurred in its use, for a variety of reasons. That survey also measures base-lines of less importance with an apparatus much less elaborate. The Geological Survey measures its principal base-lines with the apparatus used by the Coast Survey for the measurement of its base-lines of secondary importance, and also uses an apparatus devised in the Geological Survey, which is still more simple and less expensive. Thus the Coast Survey measures a base-line with great accuracy. The error in such a line probably never exceeds some small fraction of an inch. The Geological Survey measures a base-line with less accuracy; but the error must always fall within 2 inches. The measurement of a base-line of the first order in the Coast Survey costs from ten to twenty times as much as the measurement of a base line in the Geological Survey, the two lines being of the same length.

(*b.*) Both organizations determine latitudes and longitudes by the same astronomic methods.

(*c.*) Both organizations determine fundamental lines of levels, to which other levels are referred. The Coast Survey measures on the ground long lines of levels by refined methods. The Geological Survey rests its fundamental leveling upon the network of levels derived from railroads, corrected and adjusted by methods which I have previously described to the Commission.

(*d.*) Both organizations execute a grand triangulation for the establishment of fundamental points to be used as reference points in all subsequent work. The Coast Survey triangulation is of geodetic character and refinement. To do the work by this refined method, towers and other forms of signal stations are constructed. Each point is occupied by a small corps of observers for weeks or months, when necessary, the length of time being determined by the condition of the atmosphere. The purpose of this is to obtain a long series of observations with the instruments, the mean of which is taken as the true determination. The Geological Survey occupies such a point but a few hours in one day. There are occasions when two and even three days are employed; this arises when the first day selected proves to be unfavorable by reason of atmospheric conditions. In the determination of these fundamental points there is another difference. The Coast Survey selects points in such a manner that the best geometric figures will be produced. The Geological Survey also, to a limited extent, is guided by geometric conditions, but to a much larger extent it selects points which are most readily discerned by the topographers in traveling over the country. As the points are selected for geometric reasons in the Coast Survey, such points are often in positions where they cannot be seen from other points in the grand triangulation with which they are to be connected. In such cases the Coast Survey erects towers, and in forest regions the Coast Survey makes lanes through the forest, to obtain lines of sight, by cutting down the trees. These difficulties are avoided in the Geological Survey; first, by sacrificing the geometric form and selecting instead points more salient and more easily discerned; and in addition to this it uses a number of minor devices, the explanation of which would require unreasonable time. Thus it is that the geodetic triangulation is many times more expensive than the topographic triangulation.

(*e.*) The Coast Survey supplements its work by gravity determinations; the Geological Survey does not.

The classes of work enumerated in *a*, *b*, *c*, and *d* above constitute all that work necessary for the preparation of the skeleton of the map. In all of those operations the methods of the two organizations are alike in kind, but unlike in degree, the Coast Survey methods being in every respect more refined except in astronomy.

Having obtained the essential materials for the skeleton of the map, the two organizations proceed thereafter by methods more widely differing to accomplish purposes which are radically different.

In the interior, the Coast Survey ends with the completion of the geodetic work above described, but on the margin of land adjacent to the sea, where that organization constructs charts, it proceeds to make those charts in the following manner: Within the geometric figures fixed by the geodetic triangulation it establishes a second system of figures by triangles of smaller size. These secondary figures are measured still by the refined methods of the Coast Survey, except that the observations at the several points are not extended over such long periods of time. When the observations are made for these interior triangles, they are computed and the positions fixed with a high degree of mathematic accuracy. Again, within this secondary system of triangles, triangles of a tertiary system are constructed, still measured with accuracy and still computed. At this stage of the work the Coast Survey changes its method, for the reason that it now comes to the condition where it must take into consideration the objects to be placed upon the map. Up to this time it has only fixed points, marked by flags and other devices; now it must fix the position of the natural and cadastral features to be represented.

In this work it enters the field with a plane-table, which is simply a portable table erected on a tripod. The position of the table in relation to points of the tertiary triangulation is fixed by trigonometric construction. From this plane-table point the natural and artificial features of the country are fixed by the use of stadia methods of measurement, and to some extent the tape-line. It is in this manner that all of the positions of those details to be put upon the map are established, and they are put upon the map on the plane table in the field.

The Geological Survey, having its fundamental points established as above described, enters the field with its corps of topographers, and commences work at once with the plane-table supplemented with the gradientor, and in mountainous areas with the barometer. The plane-table, as used in the Geological Survey, is an apparatus of triangulation as well as being a field table for the draughtsmen.

The topographers with these instruments execute an elaborate triangulation of different degrees, reducing the larger triangles to smaller and still smaller size, until all the points needed in the delineation of the features of the maps are fixed. All of this work is done at once, that is, by going over the ground but once instead of going over the ground three times, as in the Coast Survey. The system of triangulation, too, proceeds upon a radically different plan, and instead of computing the triangles, they are *constructed* by well-known trigonometric methods. Thus all the horizontal positions of the topographic features are fixed. At the same time, by the same parties, the vertical positions of these features are fixed by simple methods of constructive triangulation and by the use of the barometer in mountain regions. The meanders of highways are determined by traverse methods in large part, but other methods are introduced when conditions are favorable.

Thus it will be seen that the most important contrasts between the two organizations exist in the manner of ascertaining on the ground and fixing on the map the positions of topographic details. The Coast Survey endeavors to give its topographic determinations with a degree of refinement commensurate with its geodetic work, and to this end employs refined methods of instrumentation and calculation, and uses direct measurements and computations in nearly all stages of its work to the minutest details—proceeding as if upon the theory that a cadastral survey would result therefrom and that the boundaries of estates would ultimately be established thereby; for these more exact measurements cannot be represented upon the map. The Geological Survey endeavors to adjust its methods to the requirements of map making, and to this end employs constructive and graphic methods in subordination to computed triangles; and in doing this work it neglects cadastral details and pays the greatest attention to the natural details.

It will thus be seen that the Coast Survey in constructing charts of inland areas pays primary attention to the cultural features of the map; the Geological Survey primary attention to the natural features. Cultural features are of two classes—those of public importance, such as highways, village, town and city sites, &c., and those of private importance, which I have called cadastral details; and it is chiefly in respect to cadastral details that the two systems disagree. Now, cadastral details are minute as compared with natural details, as a ditch is smaller than a creek or a river; a fence smaller than a natural ridge; a house smaller than a hill or a mountain. In order to introduce upon a map cadastral features it is necessary that the scale of the map should be very much larger than is necessary for natural features. For this reason the Coast Survey constructs charts usually upon a scale of one ten-thousandth, or about 6 inches to the mile; the Geological Survey constructs topographic maps of the interior on varying scales, but chiefly the three following, viz: one two hundred and fifty thousandth, or about 4 miles to the inch; one one hundred and twenty-five thousandth, or about 2 miles to the inch; one sixty-two thousand five hundredth, or about 1 mile to the inch. It constructs maps of some small districts on larger scales.

Such are, substantially, the differences in the methods of survey and in the construction of maps under the two organizations.

I have already explained that the fundamental points for a geodetic survey are selected on a different principle from those selected for the fundamental points of a topographic survey; in part such points would coincide; in part they would be different. It thus happens that the fundamental points in a geodetic survey can rarely be used as the fundamental points in a topographic survey. It is for this reason that the grand triangulation for geodesy can only in small part subserve the purposes of the topographic survey. It is therefore of very slight value to the topographic survey that the geodetic survey should precede it. On the other hand, the geodetic survey must have a reconnaissance made antecedent to the geodetic survey proper for the purpose of selecting its points. If a topographic survey be made first it constitutes a reconnaissance survey for the geodesist, and with the topographic maps the geodetic points can be selected in the office and the reconnaissance survey thereby becomes unnecessary. From the best information which I have, after having studied the matter with some care, I am of the opinion that 33⅓ per cent. of the cost of the geodetic survey would be saved by making it follow a topographic survey. In some regions 5 per cent., in other regions 10 per cent. would be saved to a topographic survey by making it follow a geodetic survey.

III. *The degree of accuracy reached by the two organizations.*

Just what degree of refinement is actually attained by the two organizations can be set forth better by a few illustrations. In the Coast Survey work the probable error in the length of the Kent Island base, in Chesapeake Bay, is $\frac{1}{228,000}$th part of its length; of the Peach Tree base, near Atlanta, $\frac{1}{561,880}$th part of its length. In the Geological Survey the probable error of the Wingate base is $\frac{1}{150,000}$th part of its length; of the Malvern base, in Arkansas, $\frac{1}{170,000}$th part of its length. Errors in triangulation are defined in terms of arc, and relate to the closure of triangles. The errors in the triangulation of the Coast Survey from the Peach Tree base are not more than half a second for each angle. In the Geological Survey the average error in the closure of triangles, in all of that work in the Appalachian Mountains, executed in 1882, 1883, and

1884, is less than 8 seconds for each angle. The probable average error of lengths of lines measured by the Coast Survey from the Kent Island base is stated to be about one-half an inch in a mile. The probable average error of the lines measured by the Geological Survey in the triangulation in the Southern Appalachians is about 6 inches to the mile, *i. e.*, in a line 20 miles in length the error would probably be 10 feet.

The above illustrations are believed to fairly represent the degree of accuracy attained by the methods of the two organizations.

The largest errors in the work of the two organizations arise from the astronomic determination of latitudes and longitudes. These have their origin from four sources: (*a*) imperfect instrumentation; (*b*) the imperfect determination of the position of stars; (*c*) the imperfect determination of the figure of the earth—a geodetic error; (*d*) deflection of the plumb line due to unknown geologic conditions. The degree of error arising from these four causes is the same in the work of the two organizations. These errors are of such a nature that their magnitude cannot be accurately determined, though known to exist, and it is the function of a geodetic survey to eliminate the more important.

There is no substantial difference in the accuracy of the charts of the Coast Survey and the topographic maps of the Geological Survey *as maps.* As distances are computed in the office the more refined methods of the Coast Survey show greater accuracy in the computations of the topographers; but this greater accuracy has no effect whatever upon the maps themselves. If we measure a distance of 40 miles by a method the probable error of which is 10 feet, and by another method the probable error of which is 10 inches, the computations in the office will exhibit that difference, but that difference cannot be shown in the construction of the map itself, and, in fact, a much greater error than that would be inappreciable upon the map. The methods of measurement adopted by the Geodetic Survey are adapted to geodetic and cadastral work, where inches of distance are of moment; the methods of measurement adopted in the Geological Survey are adapted solely to map-making purposes, where inches have no meaning.

IV. *With regard to the comparative cost of map-making by the two organizations.*

It is necessary to state that a proper comparison cannot be made. It is much like comparing the cost of a horse with the cost of a house, as the two organizations make maps of a different character and for different purposes.

From the reports of the Coast and Geodetic Survey the cost of map-making does not appear. The cost of hydrographic, geodetic, and land-cartographic work is not separated in such a manner that a comparison can be made. But, from my knowledge of the subject, and such an analysis of the elements of cost as I am able to make, I am of the opinion that such maps as the Coast Survey has made on the margin of land adjacent to the sea, if extended over the United States on the usual scale adopted by that organization—$\frac{1}{10,000}$—would cost about $100 per square mile.

With regard to the general triangulation or geodetic survey of the interior of the United States, the cost would greatly vary according to the plan adopted. If it is proposed to extend over the country a gridiron of triangulation belts, say at a distance of about 100 miles apart, the cost of such a geodetic survey would probably not be far from $2 a square mile, including in that all the astronomic work, the hypsometry or leveling, measuring of bases, triangulation, and gravity determinations. Such a system would perhaps be sufficient for purely geodetic purposes, but in order that this triangulation may ultimately be used for cadastral purposes, as I have explained in a former communication, it must eventually be developed over the whole country instead of in narrow belts across it, in which case it will cost probably not less than $12 per square mile.

The cost of the topographic survey, which is precedent to the geologic survey, and which makes maps subserving the purposes above enumerated, is greatly variable in different portions of the country. There are very large areas of the prairies and plains where the cost will not exceed $1.50 per square mile. In the mountainous and arid regions of the country west of the 100th meridian the cost will vary from $1.50 per square mile to $3.00 per square mile. In those portions of western Oregon and western Washington Territory which are densely covered with forests the cost will be about $5 per square mile. In the eastern portion of the United States where forests prevail but where the rectangular surveys have been extended so that the roads in the main follow right lines, the cost will be from $2.50 to $3.50 per square mile. Still farther east, where forests prevail, and where the roads meander through the country, the cost will be about $5 per square mile. These estimates include all elements of cost in the production of topographic maps—leveling work, topographic work, astronomic work, triangulation, &c.—but do not include engraving and printing.

These estimates are based upon experience in surveying, upon various scales, areas comprising some 300,000 square miles.

The above statements are made on the theory that maps are to be constructed in the far West on a scale of four miles to the inch. But in some portions of the East the Geological Survey is, in conjunction with State surveys, constructing maps upon a scale of one mile to the inch. These maps will cost $10 per square mile, only one-half of the expense being borne by the United States.

It may be asked whether the scales adopted by the Geological Survey are sufficient for practical purposes, and the reply to this should be that for all purposes except geology the scale is probably ample, but that there will be limited localities where this scale will be insufficient for geologic purposes, and to some slight extent maps on a larger scale must be constructed. It should further be noted that should it be found advisable in the future to enlarge the scale of the maps of any district of country, by reason of the development of the country and the dense settlement of certain districts, the topographic maps constructed on the scales now adopted will not be thrown away; the new surveys can take up the work from the basis of the old surveys, and all the work of the old surveys can be utilized, and the new surveys can be made with a relative diminution of expense. This as been proved by actual experience in many parts of the world. It must be understood that this statement depends on the fact that the topographic work of the Geological Survey deals chiefly with natural features; if it dealt chiefly with cadastral features the statement would not be true. But it should be stated that in the event of a new survey by reason of a change of scale, a re-engraving of the maps becomes necessary, and to this extent there is an additional expense.

The estimates above given for the cost of a topographic map do not include the engraving and printing of the maps. At the present stage of the work it is impossible for me to give estimates of this element of expense. For ten or twelve years I have been carefully studying this branch of the subject, and making many experiments for the purpose of discovering the best methods of representing topographic features and the most economic methods of reproducing maps from the drawings of the topographers, and have not yet reached a conclusion. The experiments made within the past three years have cost $5,850, but the work produced is not quite satisfactory. The following are the fundamental considerations that enter into the problem: First, the maps should represent those characteristics which will be more permanent, in order that it may have more enduring value; second, the maps should represent all the important characteristics that are needed for industrial and scientific purposes; third, the system of representation should be simple, so that the maps may be intelligible to all people; fourth, the method of representation and engraving should be economic, for the area to be mapped is great, and the total expense will be considerable. I am sanguine that the problem of the reproduction of maps is practically solved, and that experiments now nearly complete will prove satisfactory and fulfill the conditions enumerated above.

In planning the work for a topographic survey of the United States it has been necessary to consider that the area to be surveyed is very large—about 3,000,000 square miles, exclusive of Alaska, and with Alaska about 3,500,000 square miles. The survey of a region so vast must necessarily be at a great aggregate cost, and the economics relating thereto should be duly weighed.

The area and cost being great, the time for the execution of such a survey must necessarily be long, that the cost may be distributed over many years; but the needs for topographic maps are so many and so great that the time for its completion should be shortened as much as possible.

All of these considerations have been carefully weighed, and the result is the plan which I have presented to the Commission.

I have stated to the Commission that the map can be completed on the present plan, with the present organization, within twenty-four years, but the demands for such a map are so urgent that the work ought properly to be completed in a shorter period. Since the organization of the Geological Survey, Congress has, by increased appropriations, expanded its work from year to year, and the Director has earnestly desired and hoped that this growth would continue, so that a map of the whole country could be completed by the year 1900, and he has steadily and vigorously worked to that end. He has tried hard to develop a plan which should not be impracticable on account of excessive cost, and which should not be without substantial value by reason of imperfect methods and results. He has also endeavored to develop the plan in such a manner that no work would be lost, even though the needs of the distant future should demand more elaborate work than the wants of the present time, and that all work done should have enduring value.

By Mr. HERBERT:

Q. Is your work benefited practically by the geodetic work of the Coast Survey, or not?

A. If the geodetic survey was extended over the United States antecedent to the topographic survey, it would reduce the cost of the topographic survey from 5 to 10 per cent.

Q. But the cost of the geodetic work would be a great deal more than it would save your work?

A. Yes, sir.

Q. Have you found it necessary to make, to any great extent, corrections of your work by reason of defects discovered by subsequent geodetic survey in the same territory?

A. We have had no opportunity to test it in that manner.

Q. You have not, then, availed yourselves of any errors that have been discovered?

A. The Geodetic Survey does not go over the ground at the same rate as the Geological Survey. Where the Geodetic Survey had previously been made, we use it so far as we can.

Q. But where the Geodetic Survey has succeeded yours?

A. It has never yet succeeded us anywhere. It has gone on the same ground again, but has never completed the work. You see it takes years to complete this geodetic work, and we have been only three years in their neighborhood. They have never completed any triangulation on the ground which we have previously occupied.

Q. So that practically they have made no corrections of work that you had done?

A. No, sir; and they could probably make no corrections that would affect the maps.

By the CHAIRMAN:

Q. You stated that the topography of one-fifth of the United States is complete. That includes the Western Territories and some portions of the older regions of the country?

A. Yes, sir.

Q. State, in a general way, what portions of the East have been completed.

A. You will remember, perhaps, Mr. Chairman, that I presented a map to the joint commission some days ago, setting forth this matter very fully, and as directed by yourself, I have had that map engraved so that it will accompany my former statement.

Adjourned, to meet at Fort Myer to-morrow, Saturday, at 11 o'clock a. m.

FURTHER STATEMENT BY THE DIRECTOR OF THE GEOLOGICAL SURVEY.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, February 6, 1885.

Hon. W. B. ALLISON,
Chairman Congressional Joint Commission, &c.:

SIR: I have the honor to acknowledge the receipt of the following letter of inquiry:

SENATE OF THE UNITED STATES,
COMMITTEE ON APPROPRIATIONS,
Washington, January 27, 1885.

DEAR SIR: Will you kindly send to the Commission for its use a short summary of the methods adopted in other countries for conducting topographical surveys; also geologic surveys; and also, in a general way, inform us how cadastral and geodetic surveys are made in the various countries? The Commission is of opinion that this information will be of value.

Respectfully yours,

W. B. ALLISON,
Chairman.

Maj. J. W. POWELL,
Director, Geological Survey.

In compliance with the above request I have the honor to make the following statement:

As understood by myself, the purpose of the inquiry is to obtain an account of administrative methods and plans, as distinguished from scientific methods, which are necessarily wholly technical. Upon this theory I have proceeded in preparing my statement. I beg permission to premise a general statement, which, I think, will make the facts relating to the geographic work of the several countries embraced in the paper more readily intelligible.

A *geodetic survey* is executed for the purpose of determining the form and size of the earth. Such survey does not necessarily cover the entire surface of the country, but only connects points distant from each other, say, in a general way, from 20 to 50 miles, along narrow belts, the belts being parallel and two or more degrees apart, usually in two systems intersecting at right angles and constituting what is called a "gridiron." For geodetic purposes alone such triangulation is sufficient. In order that it may have further utility, the determined points within the belts of triangles must be greatly multiplied, by constructing within the larger figures many smaller triangles of a second order. Then these triangles must again be subdivided by another system of the third order. For other utilities, these triangles of the third order must be subdivided again into triangles of the fourth and fifth order. The order of triangles refers, of course, to their size, that is, the length of their lines. The belts of triangles having been thus cut into small figures with short lines, the great spaces between the belts must be covered with a like system of triangles of the first, second, third, fourth, and fifth orders in order to subserve all of their purposes.

Topographic surveys are made for military purposes and for industrial and scientific purposes, as set forth to the Commission in a former statement. A topographic survey of any value is based upon triangulation, and chiefly executed in its details by methods of triangulation. In its execution a purely geodetic survey is of but slight assistance, but if the geodetic survey is expanded so that the whole country is covered with a secondary and tertiary system ot triangulation, these secondary and tertiary points can be taken up and utilized in a topographic survey.

A cadastral survey is executed for fiscal and proprietary purposes. The value of a cadastral survey depends upon the degree of accuracy with which it is accomplished. Such surveys are not always based upon triangulation, but to thoroughly subserve their purposes they ought to be based upon geodetic work of the greatest refinement. If a geodetic triangulation has been executed, and the secondary and tertiary triangulation also finished as explained above, it becomes necessary to execute a triangulation of the fourth and fifth orders, as a basis for cadastral surveys, so as to have datum points fixed at the rate of about one for each two-square miles, and these points should have permanent marks on the ground.

The surveys defined above are the only geographic surveys included in the interrogatories; but another class of surveys is executed by most Governments, which should be defined here as necessary to this presentation of the subject. In general, *engineering surveys* are executed as preliminary to the construction of works, such as railroads and canals, river and harbor improvements, drainage systems, &c.

All civilized nations have, to a greater or less extent, made the surveys enumerated above. For two hundred years they have been in progress, and hundreds of millions of dollars have been expended in their prosecution, so that the methods and utilities of such surveys are no longer questions of experiment. The experience gained at so great a cost is a fruitful source of principles to guide in the control and execution of all these classes of work, alike in administrative and scientific methods.

THE ADMINISTRATION OF GEOGRAPHIC SURVEYS.

It will be seen from the account given below that geodetic operations have usually been under the control of civilian scientists, but that military engineers have usually taken part in the work.

It is further to be observed that topographic surveys were first instituted for military purposes, and that primarily topography was a part of military science, but that in modern times the discoveries of science have been applied to industries to such an extent that topography has finally come to be of much more importance to scientific industries than to scientific warfare. Under these circumstances the control of topography is gradually passing out of the hands of military engineers into the hands of civil engineers. It is further shown that civil and military engineers in most countries are, in conjunction, engaged in making topographic surveys, but that in some cases the topographic surveys are under the charge of civil departments, in others under the charge of military departments. In the great industrial nations the work is controlled, and in the main executed, by civilian officers. In the great militant nations the armies absorb the organizations.

Cadastral surveys are usually under the charge of a civil department, but often military officers are detailed to aid in the work.

With regard to geographic surveys, as with many other scientific operations, for more than a century there has been rivalry and competition between military and civil engineers for their control and execution. In the early history of this contest it was urged that such work was chiefly for military purposes, and that therefore the work should be under military control. In the later years it has been urged that the work is now chiefly for civil purposes, and that therefore it should be under civil control. It has been urged by civilians that it is impossible to engage the highest talent in such work by military methods; that great scientific men cannot be selected in their youth, before the development of their talents; that such men cannot be known until they have developed themselves, and that any system of organization for scientific work which excludes the scientific men of the country must always be perfunctory and of small value.

Military methods of promotion are peculiar. In the main they are by seniority in time of peace, and for special services in time of war. The theory of promotion is this: An army is organized for militant purposes; all plans, methods, and duties are subsidiary to success on the battle-field. Success is the ultimate criterion of a soldier's qualities. In time of peace there is no criterion of soldierly excellence; the soldier must wait for the time to arrive when his qualities may be tested; under such circumstances it is the theory that promotion should be made by seniority. But in time of war the rule of seniority is held in abeyance, and soldiers are promoted because of their qualifications as exhibited in warfare; then the criterion of excellence replaces that of seniority. In civil service, excellence is determined by the successful accomplishment of work from day to day, and promotion is based thereon.

When military organizations have been maintained for these purposes, compromise has been attempted by including civilian employés in the organization; but it is found that the real scientific men of the country are, in the main, unwilling to enter organizations where their positions are hopelessly subordinate, where advancement is impossible, and where the honors that accrue from scientific success are absorbed by perfunctory commanders.

Again, it has been urged by military men that military administration is more efficient by means of its centralized organization, and because of its power to compel strict obedience and prompt action under the sanctions of military law. On the other hand, it is urged that a centralized control of scientific work lowers the standard of work, because it to a large extent fails to take advantage of the suggestions, inventions, and improvements that arise from those who are actually engaged in executing the work, and who alone are competent inventors; and it is further urged that all surveys which depend for their integrity and vigor on punitive sanctions instead of profound interest in the work itself, have but slight value; and that scientific men are, as a class, the most radical democrats in society—patient, enthusiastic, and laborious while engaged in work in which they are thoroughly absorbed, by methods which command their judgments, but restive and rebellious when their judgments are coerced by superior authority. It is claimed that scientific men should be engaged to do scientific work under such conditions as will secure their most hearty co-operation; and that it is an outrage to use punitive measures to secure their best work—that it is but the method of the despot.

The history of the last century of official scientific work throughout the world exhibits a steady progression from military principles and methods of administration to civil principles and methods of administration.

But there is another question of administration to be considered, namely, what surveys should be prosecuted by the General Government and what surveys should be prosecuted by the States?

Cadastral surveys are made for fiscal purposes, chiefly relating to taxation, and for proprietary purposes, chiefly relating to the extent of holdings. To be utilized for these purposes they must be recognized as official by the authorities who control fiscal operations, and by the authorities who are the custodians of land records, and by authorities who sit in judgment over cases that arise in controversy. In America these fiscal powers are not assumed by the General Government, but by municipal authorities, that is, by the States and the inferior governments which they create, as counties, towns, and cities. Again, the records of titles are in the custody of municipal authorities. When cases relating to the boundary-lines of estates arise the courts of original jurisdiction are those of the lowest order of municipalities, and which are created under State law. For these reasons it will be seen that cadastral surveying does not fall within the province of the General Government, but lies within the province of the States and the minor municipal authorities created by the States.

I have shown in a former statement that the grand triangulation upon which ultimate geodetic surveys must necessarily rest should be executed by the General Government, for if the several States should desire to execute geodetic surveys for themselves, for the proper accomplishment of this work it would be necessary for them to organize an inter-State system of geodesy, as in Europe it has been necessary to organize an international system of geodesy. But an inter-State system of geodesy is a national system of geodesy, for the States cannot enter into an alliance and make treaties with each other and establish an incipient government outside of the purview and authority of the General Government.

It is manifest that topographic surveys should be executed by the General Government, first, because the boundary-lines of States are artificial; to a large extent they do not appear in nature. Topographic features cross boundary-lines regardless of State rights. Second, because the General Government requires topographic maps for the proper performance of its functions. It requires them for military purposes, for postal routes, and for the information necessary to the regulation of inter-State commerce; and they are required to give the information necessary to intelligent legislation on a great variety of subjects, such as the distribution of the mineral wealth of the country, the protection of the people from the floods of great rivers, especially as rivers stretch beyond State lines. But more than that: as maps are necessary for a great variety of scientific and industrial purposes, so that there is a demand for them from the people, they should be given to the people at the least cost. There are forty-seven subordinate governments as States and Territories. To make a topographic survey over the entire country by States, it would be necessary to support forty-seven distinct topographic organizations, each with its corps of specialists, and the forty-seven organizations would execute the work at an expense far exceeding that by which it could be executed under one organization. Wise statesmanship, therefore, demands that the Government of the United States should do the topographic and geodetic surveying, and that the States, directly or through their subordinate municipalities, should do the cadastral surveying.

THE RELATION OF TOPOGRAPHIC, GEODETIC, AND CADASTRAL SURVEYS.

The first thing to be noted is that a gridiron system of geometric figures seems to be sufficient for a geodetic survey, supplemented, of course, by the necessary astronomic and gravity determinations; but a net-work of figures extended over the entire country is of superior value. If, however, the survey is conducted purely for geodetic purposes, the additional cost of the complete net work is not warranted. On the other hand, a complete net-work is needed if the survey is to be ultimately utilized for cadastral purposes. Under these circumstances it is better to complete the net-work with geodetic refinement, because the same degree of refinement is necessary for cadastral purposes; but when such a complete net-work has been executed over the entire surface of the country, so that the best possible geodetic system has been made, it is yet insufficient for cadastral purposes. Within the geometric figures established for geodetic purposes about four more inferior orders of triangulation are necessary to establish the points to be used as the basis of the cadastral survey. The cost, then, of a grand triangulation of geodetic refinement which shall serve all geodetic and cadastral purposes will be more than six times as much as a triangulation for purely geodetic purposes.

It is further apparent that if a refined triangulation be completed over the entire country for geodetic and cadastral purposes the points thus established may be used in a topographic survey, and a triangulation for a topographic survey is thereby rendered unnecessary. It further appears that if both the geodetic and cadastral surveys be executed by the best methods, a topographic survey in the field becomes a matter of slight expense, as a topographic map can be compiled in large part therefrom, and but small additional expense for field-work is involved.

On the other hand, if a topographic survey be made antecedent to a geodetic survey, such survey may be planned in the office without a preliminary reconnaissance, and the cost of the geodetic survey materially diminished thereby. Again, it is shown that a cadastral survey can be executed with less cost if a topographic survey has preceded it, from the fact that the topographic survey furnishes the cadastral survey with its altitudes; so that altogether, as a question of expense, it is shown that it is advantageous to complete the topographic survey of a country antecedent to its geodetic and cadastral surveys.

Again, there is an urgent and immediate necessity for topographic maps; there is not an urgent and immediate necessity for a geodetic survey; and a cadastral survey becomes necessary only when landed property reaches such a value that accurately fixed boundary-lines and accurately determined quantities are of financial importance. It is manifest, therefore, that a topographic survey should first be made, then a geodetic survey, and finally a cadastral survey; and such has been the order in most of the countries of the civilized world.

THE GENERAL SYSTEMS OF MAPS NEEDED.

It has been mentioned that topographic maps were originally made for military purposes. As wants were developed for scientific, industrial, and cadastral maps, an attempt was made in various countries to construct a single map which should subserve all wants, and maps constructed on this theory have been made from time to time. But experience has abundantly shown that all of these purposes cannot be subserved by one map. The facts that it is necessary to represent cannot be included on one sheet, as they obscure each other and render the map unintelligible. Experience has also shown that these maps cannot be constructed on the same scale. Three general classes of maps have been developed and pretty thoroughly distinguished from each other, namely, general topographic maps, cadastral maps, and military maps. General topographic maps are usually constructed in such a manner that many subsidiary charts may be derived therefrom. Thus, from the general map, drainage maps, hill maps, road maps, etc., may be directly compiled, and the general maps may be used as a basis for geological maps, agricultural maps, forestry maps, sanitary maps, statistical maps, etc., on the same or on reduced scales. Such maps require no additional expense for topographic surveying in the field.

THE BEST METHOD OF CONSTRUCTING TOPOGRAPHIC MAPS.

THE FACTS TO BE REPRESENTED.

The first question of importance in a plan for a topographic survey relates to the facts which should be represented upon the map. For all purposes for which a topographic map is made, except the functions of a military map, the natural features of the country are of prime importance. The natural features, therefore, should be represented. Of the artificial features there are two classes: Those which may be included under the term public culture, relating to the sites of towns and cities, and of highways of all classes—canals, railroads, and wagon roads; all of these should be put upon the map. There is another class of artificial features, which relate to private properties. These are houses, fields, orchards, &c., and, as they relate to private property, or estates, they may be called cadastral features. These should not be placed upon general topographic maps for the following reasons: First, they are so minute that they cannot be properly represented without enormously increasing the scales. Second, their delineation upon the map obscures the conventional characters used to represent natural and public topography, and to the extent that they are introduced the more important features are obscured; the map becomes more complex and less easily interpreted. There is yet another potent reason for their exclusion. When a map has been constructed it must be maintained to be of permanent value. The natural features remain, the cultural features are changeable, and those cultural features which have been denominated "cadastral" are the most changeable. If they are represented upon the topographic map constant revision becomes necessary, and this can be accomplished only at great cost. For all these reasons it is manifest that cadastral topography should not be placed upon a general topographic map.

METHOD OF REPRESENTING TOPOGRAPHIC FACTS.

The exclusion of many facts from topographic maps greatly simplifies the system of conventional signs necessary for use. Wide experience has led to a system from which there is little departure in the various countries of the world. The more important points to be mentioned here are the following:

First, relief features are no longer represented by hachures, but by contour lines, which more thoroughly convey specific facts relating to elevation, and a contouring system is much less expensive than a hachuring system.

Second, to clearly distinguish the different elements of topography, colors are introduced upon maps. There is yet some diversity in the methods of using colors, but the best systems adopt blue for the drainage and all bodies of water, black for culture and names, and brown for contours. This is the system adopted by the Geological Survey.

THE SCALE.

The next point of importance to be considered is the scale on which topographic maps should be made. It is necessary to consider the subject from two aspects, namely, the best method of representing the facts, and the most economic method of accomplishing the purpose.

With respect to the representation of the necessary facts upon a topographic map, these two fundamental principles are controlling: First, the scale should be sufficiently large to clearly represent all the necessary facts; second, the scale should be as small as possible consistently with the proper representation of facts, in order that the largest possible area may come under one view, because all the important purposes for which topographic maps are made include large areas of country. For scientific and industrial purposes topographic maps are used to exhibit the geographic distribution of phenomena, such for example as the geographic distribution of certain classes of rocks, certain minerals, certain clays, certain quarry rocks, etc., or the distribution of lands that are to be drained, or the distribution of forests. The study of geographic distribution can best be made with maps of large area. These two considerations are apparently conflicting, but in practice it is shown that a compromise can be made without any serious sacrifice on either hand. The whole experience of the topographic surveys of Europe shows that a scale of about one inch to the mile $(\frac{1}{63360})$ is large enough to represent all or most of the facts for which topographic maps are made, and is small enough to exhibit on one sheet a sufficient area to be considered at one examination.

It is next in order to consider the scale from the standpoint of cost. The cost of making topographic surveys increases at a ratio somewhat greater than the increase of the scale. The cost of engraving and printing increases with the square of the increase of the scale; that is, if the scale is doubled, the cost of the survey will be something more than doubled, and the cost of the engraving will be fourfold. In the construction of topographic maps, therefore, the importance of the country to be surveyed should be considered, and in general the scale should be larger for densely populated and wealthy districts, and smaller for thinly populated and desert or mountainous districts. The scale should vary for the needs of the country.

The scale finally adopted by various countries for topographic maps is not exactly one inch to the mile, but they group closely about that scale, as shown by the following table. The scale given is that of publication. The scale for field-work is usually two or three times that of publication; in the Geological Survey of the United States it is twice that of publication.

Scales of standard topographic maps of foreign states.

	Scale.
France	1: 80,000
Great Britain	1: 63,360
India	1:253,440
Germany	1:100,000
Austro-Hungary	1: 75,000
Spain	1: 50,000
Portugal	1:100,000
Italy	1: 50,000
Norway	1:100,000
Sweden	1: 50,000 and 1:100,000
Russia	1:126,000
Switzerland	1: 25,000 and 1: 50,000
Belgium	1: 20,000 and 1: 40,000
Denmark	1: 40,000 and 1: 80,000
Holland	

Scales of standard topographic maps adopted by the U. S. Geological Survey.

For densely-settled regions	1: 62,500
For thinly-settled regions	1:125,000
For desert plains and the Rocky Mountains	1:250,000

SIZE OF SHEETS.

A question of minor importance, and yet of much interest in the planning of surveys, is the size of the sheets into which the map is divided for atlas purposes. It has already been stated that it is desirable to represent as great an area as possible upon one sheet, and this leads to the making of the sheets of the map as large as possible. But there are other reasons which make it desirable to have the sheets of smaller size. First, the nomenclature placed upon the map should be as small and inconspicuous as possible, in order that it may not obscure the topography proper. Again, in order that the greatest amount of detail possible may be represented upon a map of a given scale, it is necessary that the engraving should be as fine as possible; but fine engraving and lettering cannot be read at a great distance from the eye, and hence all the materials on a large sheet cannot be brought into one view, but the eye or the sheet must be moved to grasp the whole of it. For this reason small sheets are considered desirable. There is still another reason why small sheets are used: They are more conveniently bound into atlases, and more convenient to handle, and more conveniently preserved in libraries.

In order that topographic maps may be readily intelligible to all classes of people, it has become a general practice in Europe to use different colors for the representation of different classes of facts, and this plan adds greatly to their value. But maps that are printed in colors must go through as many processes of printing as there are colors used, and it is found in practice that the different impressions made in the several processes of printing cannot be made to "register" if large sheets are used. The smaller the sheet the more accurate may be the registering.

The following sizes of sheets have been adopted by different countries, the measurement being between neat lines.

Sizes of sheets of standard topographic maps of foreign states.

	In inches.
France	10 by 15½
Great Britain:	
Old series	24 by 36
New series	12 by 18
Scotland	18 by 24
India:	
Old series	24 by 38
New series	12 by 19
Germany	11 by 13
Austro-Hungary	16 by 21
Spain	15 by 21
Portugal	20 by 31
Norway	14 by 19
Sweden	18 by 24
Switzerland	10 by 13
Belgium:	
Scale 1: 20,000	16 by 23½
Scale 1: 40,000	19½ by 31
Denmark, for scale 1: 40,000	12 by 15

Size of sheets adopted for the topographic maps of the U. S. Geological Survey ....13½ by 17½

ENGRAVING.

Another question of minor importance relates to the method of engraving. All experience shows that topographic maps should be engraved on copper, or reproduced by some method alike refined and permanent. Fine engraving permits of smaller scale, and copper engraving may be very fine engraving. Topographic maps properly constructed require infrequent revision, and copper is enduring. When revision is necessary it can be made on copper at a minimum expense. There is yet another reason for using copper; it is that topographic maps are needed in great numbers, and when once engraved on copper they can be reproduced at a small expense.

Table showing methods of reproduction of standard topographic maps in foreign countries.

Country.	Method of reproduction.
France	engraved on copper.
Great Britain	engraved on copper.
India	engraved on copper.
Germany	engraved on copper.
Austro-Hungary	etched on copper.
Spain	engraved on stone.
Portugal	engraved on stone.
Italy	engraved on copper.
Sweden	engraved on copper.
Russia	engraved on copper.
Switzerland	engraved on copper.
Belgium	engraved on stone.
Denmark	engraved on copper.
Netherlands	engraved on stone.

THE BEST METHOD OF CONSTRUCTING CADASTRAL MAPS.

Whenever the landed interests of a country become so great that a cadastral survey is demanded, the survey should be made with all of the accuracy and minuteness necessary to establish the general topographic facts relating to the property surveyed, that is, the boundaries of estates and the general culture thereon. When such a survey is made a scale should be selected which will properly represent all of these facts; and it is shown by wide experience that the scale of 1-2500, or about 25 inches to the mile, is the proper one. By this scale one square inch represents an acre, with close approximation. Again, all of those features which cadastral surveys are designed to include can be placed upon a map of that scale in their natural or actual proportions; streams and roads can be represented with their true proportional widths; houses with their true proportional sizes, &c. But if a smaller scale is adopted, many of the items placed upon the map must be exaggerated, and thus the true proportions are lost. These considerations demand, therefore, that the scale of 25 inches should be adopted, and it is the scale adopted by most countries. Slight variations are made in the scale from country to country, because different countries have different units for land measures, but practically there is a common agreement upon this point. Cities and towns are usually surveyed on larger scales.

Scales of cadastral maps of foreign states.

	Scale.
France	1:2,500
Great Britain:	
Parish maps	1:2,500
Cities	1:1,000
Do	1:500
India	1:15,840 1:3,960
Germany	1:625 1:1,250 1:2,500 1:5,000
Austro-Hungary	1:2,880
Spain	1:2,000
Portugal	1:2,500 1:5,000
Norway	1:8,000
Sweden	1:2,000 1:4,000 1:8,000
Russia	1:8,400
Switzerland:	
Cities	1:200
Villages	1:500
Cultivated lands	1:1,000
Woodland	1:2,000
Belgium	1:2,500
Denmark	1:4,000

In many countries cadastral maps are not printed, but in some countries they are, to a manifest advantage; and when thus published something of a revenue may be derived by their sale. When so published, inexpensive and simple methods are adopted, such as photolithography or zincography.

THE BEST METHOD OF CONSTRUCTING MILITARY MAPS.

Peculiar conditions arise when topographic maps are to be used for military purposes, which must not be neglected. The military purposes for which topographic maps are used are of two classes: First, they are necessary in planning and conducting the movements of troops from one portion of the country to another; that is, they are useful for strategic purposes. Second, topographic maps may also be useful for the maneuvering of troops on the immediate theater of conflict; to discover how infantry, artillery, and cavalry may best be combined in the battle, and to show how bodies of troops may be grouped, and how outposts and pickets may be distributed when armies stand confronting each other. This may be called the tactical use of topographic maps. The two purposes are so distinct that the same map will not subserve both. The general topographic map is all that is necessary for strategic purposes, but experience has shown that for tactical purposes military maps should be on a scale of about 6 inches to the mile, and that they should represent all of the facts of importance to the stationing of troops on the eve of battle and the maneuvering of troops in the conflict. These facts are only in part found upon proper topographic maps, and only in part found upon cadastral maps.

If, then, a nation maintains a large standing army, and war impends from year to year, it is found to be advantageous to compile from cadastral maps such facts as they contain which are of value to the military maps, and to add to the same such facts as may be necessary by an actual survey on the ground. To make these maps useful it is necessary that they should be constantly revised and kept in a perfect condition; and, in order that advantage may be reaped from them which cannot accrue to the enemy, the maps must be solely in the custody of the War Department, and kept strictly as military secrets.

A CRITICAL REMARK.

I am constrained to remark on statements embraced in the record of the Commission which might possibly imply that engineering surveys for constructive purposes are dependent on the previous refinement of geodetic and topographic surveys. Doubtless this implication was not intended by the gentleman who made the statement, but possibly it might be thus interpreted.

The great irrigating works constructed and maintained by the British Government in India are in no manner dependent on geodesy, and are dependent on topography only in the selection of sites.

In the construction of engineering works, such as railroads, canals, public roads, drainage systems, and irrigating systems, topographic maps are used in the selection of routes and sites. Their use in this manner is but general, and the information which they contain is the common property of all. But when decisions are reached that such works are to be constructed along general lines, topographic maps cease to be of value; for constructive purposes special surveys become necessary. Now, such surveys are in no way related to geodesy; the degree of refinement in the geodetic survey has nothing to do with them. In like manner, topographic maps serve no further utility. The accuracy and value of the special surveys for works are independent of previous geodetic and topographic surveying.

Other statements have been made to the Commission from which it might be inferred that the topographic surveying executed by the Geological Survey can be properly denominated "exploration" or "reconnaissance." Now, a large part of the topography executed on this continent during the first century of the history of the United States, was by reconnaissance or exploratory methods; that is, the work was executed without the measurement of base-lines, and without triangulation, but simply by traveling through the country and determining latitudes, longitudes, and altitudes in a crude manner, at intervals along the route traveled, and sketching by the eye the topographic features. Such methods are usually denominated "reconnaissance" methods, and such surveying "exploration." But the Geological Survey has adopted methods entirely sufficient for all general practical topography, and when a map has once been constructed by this method no future geodetic surveying will change the map in any respect.

In former statements made to the Commission I have tried to set forth the importance of a geodetic survey. Researches in geodesy have come to be of great value to the geologist, as their results profoundly affect the fundamental principles of geology. Geodesy, therefore, is no longer of chief interest to the astronomer and physicist, but is of equal or even greater importance to the geologist. My own researches have extended into this field, and what I have written upon this subject may have contributed somewhat in directing geological research into geodetic channels. Being thus deeply interested in geodesy, I have been careful that no word said by me could be used as an argument against the most refined and thorough geodetic survey possible; and I have desired that it should be clearly understood that the triangulation under the Geological Survey was of no value for this purpose, except to furnish a general reconnaissance. For this reason I have employed the expression that the triangulation of the Geological Survey is only sufficiently refined for the purpose for which it is used. I beg that I may not be misunderstood, and that this expression may not be interpreted as a statement that the work is not sufficiently refined for topography. The triangulation of the Geological Survey subserves topographic purposes perfectly, but does not subserve geodetic purposes.

GEOGRAPHIC SURVEYS AS CONDUCTED BY VARIOUS EUROPEAN GOVERNMENTS.

FRANCE.

A general account of the geographic surveys of the world begins properly with France, for there the three branches of geographic work—geodesy, topography, and cadastral surveying—had their origin.

GEODESY.

The French Academy of Sciences was instituted in 1666, at a time when the researches of Newton had just brought into striking prominence the need of a more exact knowledge of the form and size of the earth. One of the first tasks which it set for itself was the gaining of more accurate knowledge in this respect, and to this end one of its most distinguished members was selected to measure an arc of a meridian. This was M. Picard, who in 1670 had completed the measurement of a base about 11,037 meters (nearly 7 miles) long, developed from this base by five triangles to a line about 42 miles long, and thence measured by a chain of large triangles an arc of a meridian about 78 miles long.

This appears to be the first geodetic work, properly so called, on record, and by a fortuitous balancing of errors it gave a fair approximation to the size of the earth. The Academy, stimulated by the prompt and seemingly satisfactory results of Picard's measurements, conceived the idea of extending the measure entirely across the realm from north to south. This was actually accomplished by the elder Cassini, who in 1718 had completed a chain of triangulation across France, from Dunkirk on the extreme north to Perpignan on the south, 8° 31′ in length.

At this time not only was the rotundity of the earth recognized as an established fact, but its oblate-spheroidal form was also generally accepted as being proved, (*a*) from theory, (*b*) from pendulum experiments, and (*c*) from analogy with Jupiter, which had been observed to be flattened at the poles. When Cassini's measures were examined they indicated a result opposed to this—that the earth was compressed at the equator. Thereupon an energetic debate arose in the scientific world. Compromise was impossible. The earth could not be both an oblate and a prolate spheroid.

After long and heated discussion the Academy adopted the suggestion of Maupertius and Bouguer for a solution of the matter. This was to dispatch two parties, one to the neighborhood of the equator and the other to a high northern latitude, each charged with the duty of measuring with great accuracy an arc of a meridian. The commission selected for the equatorial work consisted of Godin, Le Condamine, and Bouguer, assisted by two Spanish officers. Peru was chosen as the field of operation. They sailed from France in 1735, and after eight laborious years succeeded in completing the measure of an arc 3° 07′ long with a degree of precision that even now renders this a notable piece of geodetic work. Two base-lines were measured, one 7.6 miles long, the other 6.4, and these were connected by a chain of triangles. The northern party, under the direction of Maupertius, left France in 1736 and proceeded to Tornea, in Lapland, about latitude 66°. A reconnaissance was made, and the Tornea River, running from north to south, with high mountains on either bank, was found to afford a most favorable location for the work. A base 8.9 miles long was twice measured on the frozen surface of the river in mid-winter, when the sun just peered above the horizon at noon. The two measures differed by only 4 inches. Seven days were spent in measuring the base and sixty-three days in the triangulation or angle measurement. Then the latitude and the azimuth were determined; and thus within one year the work was completed, and an arc of 57′ 30″, intersecting the Arctic circle, had been measured.

The results obtained by comparing the Peruvian and Lapland measures confirmed the theory of a sphere flattened at the poles, and contradicted Cassini's results showing a compression at the equator. It was thus, Carlyle remarks, that Maupertius flattened the poles and the Cassinis. Then followed an examination of Cassini's work, to discover why its results were out of harmony with all the other determinations, and after much trouble it was discovered that there was an error in Picard's base measurement, and Cassini had used this erroneous base. This was remeasured by La Caille (1740–1754), and the recomputations show that, though not in perfect accord with other measures, it did not contradict them.

This brings us to the middle of the eighteenth century, and on looking back we see that France has been for a century an active agent in the prosecution of geodetic research, and this purely for scientific purposes.

I have already mentioned the meridian measurement of the elder Cassini (J. Dominique), or Cassini I, director of the Paris Observatory, who, beginning in 1683, completed the measure in 1718. He was assisted in this work by his son, Jacques Cassini, or Cassini II, who succeeded his father as director of the observatory. Cassini II was in turn succeeded in the directorship of the observatory by his son Cassini de Thury, or Cassini III, and finally Cassini III was succeeded by his son Jacques Dominique, or Cassini IV. Under the direction of these Cassinis geodetic work was continually in progress. An arc of the parallel of Paris was measured by Cassini III and Miraldi in 1734, and a longer one (2°) between St. Clair and Mt. Sainte-Victoire in 1740 by La Caille and Cassini III.

In 1783 Cassini II proposed to the Royal Society to connect Paris and Greenwich by a chain of triangles. This proposition was favorably received by England, and General Roy was commissioned on her part to execute the work. Count Cassini, Mechain, and Legendre were the French commissioners. This work, completed in 1787, was the beginning of the trigonometric survey of Great Britain.

In March, 1791, the constituent assembly received and sanctioned a project of certain distinguished members of the Academy of Sciences, among whom were Laplace and Lagrange, to the effect that a ten millionth part of the earth's meridian quadrant should thereafter be adopted as the national standard of length, to be called the meter. For determining the length of the meridian quadrant it was decided to measure, with the highest precision of which the greatly improved science of geodesy would admit, an arc of a meridian from Dunkirk, in the north, to Barcelona, on the south, 9° 40′ long. Delambre was put in charge of the northern, Mechain of the southern part, and work began in June, 1792. In 1797 the field-work was completed and turned over to a commission, which revised and verified all the calculations, and then deduced the value of the meter.

This measurement constitutes an epoch in the history of geodesy, being a marked advance on all previous work. Other European nations then began to prosecute geodetic work,—not merely measurements of arcs of meridians or parallels, but geodetic surveys; and these surveys with varying fortunes have continued to extend and improve down to the present day, when we find all Europe engaged in prosecuting such surveys on the largest and most refined scale, and working as a general confederation with common units and by common methods. This general confederation for the measurement of degrees in Europe, formed in 1862, was joined by France in 1874, and she is now engaged in prosecuting geodetic work of the highest refinement to keep pace with the general progress of the world in such matters.

This work consists of—

(1) Primary geodetic triangulation;

(2) Astronomic determinations of the latitude and longitude of the vertices of the triangles and azimuths of their sides;

(3) Leveling of precision to determine the relative heights of the oceans, seas, lakes, &c., and altitudes of important points;

(4) Tidal observations for determining the mean level of the ocean from which the heights are reckoned;

(5) Determinations of the force of gravity.

TOPOGRAPHY.

The original topographic work of France was organized and executed under the direction of the Cassinis. It was based upon a network of triangles, executed with a good degree of refinement for that time, but quite insufficient for modern geodesy. Work was completed in 1788, and France had a topographic atlas with elevations shown by hachures. During the Napoleonic wars the *Dépôt de la Guerre* was charged with the duty of making military maps, and attention was sharply drawn to the defects of the old Cassini maps. It was thereupon suggested and urged that the time had come for better maps, both general and special. The Secretary of War submitted a report upon this subject on August 6, 1817, and the Emperor ordered a new topographic survey to be executed in connection with the cadastral surveys.

A commission selected from the Academy of Sciences and from various administrative departments, headed by Laplace, was organized to prepare a plan for the work. The general conclusion reached by them was that, although Cassini's work might serve as a general model, a mere revision of it would be insufficient for the times. The commission therefore recommended, first, that a gridiron scheme of primary triangulation be extended over the whole country; and, second, that a network of secondary and tertiary triangles be expanded, that is, be made to fill in the remaining spaces, to furnish points of departure for the topographers. This was done under the direction of the General Staff of the Army. The engineers and geographers of the cadastral survey were engaged as topographers. In 1833 the first sheet of the new topographic map of France was issued.

At the geographic congress held in Paris during July, August, and September, 1875, high up in the farthest end of machinery hall hung an enormous map more than 32 feet high. At the nearest distance at which it could be seen the lettering and legends were invisible; only the hachures appeared in view, throwing into clear and striking relief the topographic features of the country, all the manifold and minute details being lost in the general effect. This was the great topographic map of France, then not quite complete, but finished three years later. Begun in 1833, and carried through on a uniform plan to completion in 1878, it stands as an enduring monument of forty-five years of patient labor.

This map is known as the "the general staff map." It is on a scale of 1–80,000, and is engraved on copper. Relief features are shown by hachures, and the elevation of important points is denoted by figures. The areas of cultivation are marked. The map is heavily encumbered with conventional signs, especially designed for military purposes. The single sheets are about 14 by 17 inches, and two hundred and seventy-four of them are required to delineate the whole country. Since the first publication from the copper-plates, later editions have been reproduced by zincography, but they are greatly inferior to the original sheets. They are sold for a franc each, and a competent critic remarks that they are "very cheap, but too dear when they are illegible."

Since the Franco-Prussian war the French have been thoroughly aroused to the importance of revising this general map, and the *Dépôt de la Guerre* is now charged with the thorough revision of it every ten years. The military topographic work is performed by officers of the staff, assisted by soldiers. The officers are men of education, being, with few exceptions, graduates of the École Polytechnique, or of Saint-Cyr, where they receive good training in topography and many other branches of applied science. Lately there has been a supplementary school established, known as the "War School," with a course of instruction designed for staff officers, to qualify them for the high duties to which they are assigned.

Various charts of France have been complied from the staff map and from the sheets of the cadastral surveys. The following are of importance:

(1) A map of France in thirty-two sheets, scale 1–320,000.

(2) A map of France in fifteen sheets, scale 1–500,000; prepared for the Depot of Fortifications, in three types. On the first, heights are shown by hachures, water in blue, and forest areas in green. The second is a road map, with contours 100 meters (about 328 feet) apart. The third is orographic, giving only the relief topography, drainage, and names.

(3) A general hypsometric map of France, scale 1–800,000, with red contours having vertical intervals of 100 meters, and printed in three colors.

(4) A railroad map of France, on a scale of 1–600,000.

(5) A map of the environs of Paris, scale 1–40,000.

Many special charts are also constructed.

CADASTRAL SURVEYS.

Cadastral surveys originated in France, and it may be interesting to give a brief account of their origin and the purposes for which they are executed. The principal source of revenue of the French Government during the seventeenth and the eighteenth centuries was from direct taxation, and heavy imposts were laid upon landed property, and especially upon its produce. This tax was distributed over the country with the greatest minuteness, in order to insure the greatest possible revenue, and the taxes were collected with rigor. The machinery of taxation was wholly centralized in the General Government, and the methods of assessment and collection were excessively inquisitorial. The revolution of 1788 profoundly modified the laws relating to tenure of land and its taxation. In 1790 the subject of general taxation, and principles governing its distribution, came under serious consideration in the Constituent Assembly which made the land tax the basis of its financial system. The assembly undertook to devise some system of taxation which could be distributed with relative equality upon all landed property and which should be less inquisitorial. To accomplish this it was necessary that a proper proportional contingent should be levied on each department, and that within each department the fractional contingent to each arrondissement should be in proportion to its value or tax-paying power, and in like manner that each arrondissement or county should distribute its contingents to the communes in equitable proportions. After many trials the system developed consisted in making a cadastral survey, which was a complete survey of all the properties of each commune, and which grouped these properties in units so small that each would be practically homogeneous and capable of ready evaluation, and then the contingent to each unit was distributed to the parcels or properties. Thus there arose a necessity for a minute survey which should be entered upon an official plat and filed in the archives of each commune, arrondissement, and department. Since the levy was largely based on acreage, extreme accuracy was necessary.

The means for making this survey had been in great part in existence for a long time, for the geodetic survey of France had been begun early in the eighteenth century, and had been prosecuted with vigor by some of the most illustrious geometers of modern times, under the auspices of the old monarchy, and the net-work of triangulation could be used with great advantage in the delineation of the new cadastres, which were the units for valuation. More or less supplementary work, however, was necessary, and it was confided to the chief geometer appointed by the central government. But many geometers with administrative ability and technical training were needed to prosecute trigonometric work over so large an area, and in addition to this two thousand assistants were required as surveyors. Such trained men were not in existence, and the minister of public instruction established a course of public training in Paris in theoretical and practical geodesy, and the graduates from this course were called cadrastral engineers. Subsequently it was ordered that no one could become a geometer or cadastral engineer without passing an examination before the professors of this school. A vast number of men were engaged on this survey, and it was quickly accomplished. The maps were constructed on a scale of 1-5,000, 1-2,500, and 1-1,250, as demanded by the characteristics of the country to be surveyed, and show the subdivisions, the land-marks, and all political boundaries. In addition to this, the streams, hills, valleys, government forests, and all natural and permanent features are represented. The geometers or surveyors constructed plats of each commune, and also topographic maps of each commune, showing its boundaries, all the natural topography, including the courses of streams, the hills and the mountains, and all roads and other important public culture. Copies of the two were furnished to each commune, to each arrondissement, to each department, and to the central government.

Although the impost upon land had been regarded by the law as in theory fixed and unchangeable, still the necessity has from time to time arisen for a redistribution of taxation, and such redistributions ha[illegible] been made, involving resurveys and corresponding changes in the [illegible] The readjustment involved some expense, which was borne by th[illegible]tricts affected, but it was quickly accomplished.

Some of the most illustrious scientific men of France have ployed in her cadastral surveys, and a large corps of skilled surveyors have been trained from time to time for this work.

This cadastral surveying has been executed partly at the expense of individuals, partly at the expense of communes, partly at the expense of arrondissements, partly at the expense of departments, and partly at the expense of the Government. The ratio of expense borne by individuals and the several political units has varied from time to time and from district to district; hence the total cost per unit of area cannot be given.

GREAT BRITAIN.

ADMINISTRATION.

Great Britain has executed geodetic, topographic, and cadastral surveys. The geodetic survey is finished. A topographic survey is not now in progress, but topographic maps are compiled. The cadastral survey is still in progress. All have been executed under one management. The organization is known as the "Ordnance Survey." Its original institution was preceded by amateur work, conducted by General Roy, then a quartermaster of the army, and by a special triangulation in which the Government of France co-operated. At the request of the French Government, the scientific men of the two nations united in the execution of a triangulation to connect the observatories of London and Paris. The field-work was performed in 1784, the portion from London to the Channel being executed by the English, and the portion from Paris to the Channel by the French, and the two systems being connected across the Channel by simultaneous observations of the two corps. In 1791, a general triangulation of the kingdom was begun, and the administration was then confided to the Board of Ordnance. This triangulation was executed by refined methods, and covered the entire country—that is, it was not a gridiron triangulation. It was completed in 1853. On the institution of the geodetic survey, topographic and cadastral work was begun, and the cadastral work still continues.

At the time of the institution of the survey, the Board of Ordnance was partly military and partly civil. The first reports of scientific results were made to the Royal Society of London, an institution having somewhat the same relations to the British Government that the National Academy of Science has to the Government of the United States. In 1870 the Ordnance Survey was transferred without change of *personnel* from the War Department to the Commissioners of Works, a governmental department resembling in some respects our Department of the Interior. This transfer was ordered "in consequence of the completion of the military map of England and Wales, and because it was not considered right that the cost of completing the cadastral survey of the kingdom should be included in the War Office estimates." The construction of maps for military purposes was practically an administrative fiction almost or quite from the start. The refinement of the first triangulation was altogether superfluous for military topography, and the initial and all other legislative regulations referred exclusively to fiscal and industrial objects. (4 and 5 Vict., cap. 30; 33 and 34 Vict., cap. 13.)

The organization is composed of officers of the Royal Engineers, civilian surveyors, sappers and buglers of the engineer corps, and civilian draftsmen, clerks, and laborers. The corps is about five-sixths civilian.

Personnel for fiscal year 1882–1883.

Commissioned officers (staff)	32
Non-commissioned officers	128
Sappers and buglers	321
Total military	481
Civil assistants	1,700
Laborers	900
Total civil	2,600
Grand total	3,081

GENERAL PLANS.

In the earlier years of the survey several scales were used, the most important of which was a scale of 1–10,560, or 6 inches to the mile; and that scale was adopted as the proper one for the kingdom. All work done on smaller scales was supposed to be temporary. After long experience it was discovered that this scale was altogether too small for cadastral purposes and altogether too large for general topographic purposes; and it was further discovered that the amount of cadastral details upon the map greatly obscured the natural topography; and, still further, that the cadastral features were rapidly changing, and that it was not possible to keep the corrections of the map up to date. The map on this scale, as reported by a Parliamentary commission, was always "hopelessly in arrears," so that it did not properly subserve any of its purposes. For many years there was much discussion in England, by publicists, geologists, engineers, military men, and fiscal officers, and especially by statesmen, on the subject of scales and methods, and many voluminous reports were made by Parliamentary commissions who investigated the subject. From year to year changes were made, and finally, as the outgrowth of this discussion and experience, the following map systems have been adopted:

I. A map of the kingdom was long ago constructed on a scale of 1 inch to the mile. Theoretically, it was designed for military purposes, and the methods of topographic representation were such as have been previously described to the Commission as "military," that is, the hill topography was represented by hachures, and it was crowded with cadastral details. This map is now being reconstructed on a new plan, the scale remaining the same. The relief features are represented by contour lines, and a minimum amount of artificial topography is represented. The details for revision are derived from the cadastral maps hereafter described. An edition of this map is prepared with hill shadings instead of contours, probably for military purposes. It is understood that a "commission of exclusion" has lately been organized for the purpose of deciding what artificial characteristics shall be left off this map in order to make it of more permanent value and to save the expense of frequent revision. This is the general map for industrial and scientific purposes.

II. The military map proper of Great Britain is on a scale of 6 inches to the mile, or 1–10,560. Revisions of certain portions of it are made from time to time by officers of the staff. The map is not published, but is held as a military secret.

III. County maps are being constructed on a scale of 1–10,560, or 6 inches to the mile. This was the original system of cadastral maps for Great Britain, and a large part of the territory has been surveyed and mapped on this scale. But it was found inadequate for the purpose. Surveying on this scale is no longer in progress, and the maps now made for the counties are reduced from the grand system of cadastral maps next described.

IV. Parish maps are being constructed on a scale of 1–2,500, or about 25 inches to the mile, for all portions of the country, except as follows:

First. All towns of more than 4,000 inhabitants are mapped on a scale of 1–500, or about 10 feet to the mile. Large cities are surveyed on a scale of 1–1,056, or 5 feet to the mile.

Second. The survey of Ireland was originally completed on a 6-inch scale, and that map is undergoing revision on the same scale, except that towns and cities are mapped on the scales used for other towns and cities of the Kingdom.

At the present time all surveying of Great Britain, except the revision of Ireland, is on the 25-inch, 5-foot, and 10-foot scales by which the parish maps are produced, except a little military surveying from time time for secret maps.

The county maps are made from the parish maps by mechanical reduction, and the map of the kingdom on the scale of 1 inch to the mile is under revision, the new data being compiled from the parish maps. The general topographic map is engraved on copper. The county and parish maps are reproduced by zincography, a cheap mechanical method, comparable with photolithography as used in America.

COST.

In a general report made on the occasion of turning the Ordnance Survey over to the Department of Works (1870) the director estimated the expense of cadastral surveying on the scale 1–2,500 at £32 ($154.88) to the square mile, and on the 6-inch scale at £18 13*s.* 4*d.* ($90.35). This estimate is fortified by the statement that the preceding estimates for twelve years fell only £5,000 ($24,200) short of the actual cost.

Comparing the total appropriations from 1874 to 1881 with the reports of work accomplished it appears that the cadastral work has cost for that time an average of £71 8*s.* ($345.58) per square mile. This includes work on the scale 1–2,500, and also work on the scales 1–500 and 1,056, the relative amounts of which are unknown; but it may probably furnish a fair estimate of what the average cost will be for surveying the United Kingdom on the several scales adopted.

The revision of the cadastral map of Ireland on a scale of 6 inches has been in progress for a number of years. From reports of the progress of the work, including area resurveyed and the expenses of the same for a period of eight years, it appears that the cost of this revision will be about £32 ($154.88) per square mile.

The expense of the geographic work for the fiscal year 1882–'83 was £249,028 ($1,205,295.52).

INDIA.

ADMINISTRATION.

Since the beginning of the century, geographic surveys have been in progress in India. Prior to 1878 the work was carried on by three distinct organizations, known respectively as the Great Trigonometrical Survey, the Topographical Survey, and the Revenue Surveys. In 1878, the three surveys were consolidated, and the new organization placed under the Department of Home, Revenue, and Agriculture.

In 1877, just before the consolidation, the organization of the geodetic survey comprised 67 persons, of whom 51 were civilian engineers and 16 were detailed from the army, chiefly from the corps of Royal Engineers. At the same time the Topographical and Revenue Surveys employed 723 persons, of whom 72 were detailed from the army, 392 were civilian surveyors from Europe, and 259 were natives. The salaries of the Europeans ranged from 2,565 rupees (a rupee being about 50 cents) to 120 rupees per month. The pay of native assistants was very low.

The personal organization at the present time is composed of officers of the Indian army and of the Royal Engineers, European civilians, and natives. This organization is as follows:

A surveyor-general in charge of the whole work, who is superintendent of the trigonometrical and topographical branches.

A deputy surveyor-general, who is superintendent of the revenue branch.

Deputy superintendents:	
First grade	4
Second grade	10
Third grade	12
Assistant superintendents:	
First grade	11
Second grade	11
Third grade	12
Surveyors:	
First grade	9
Second grade	12
Third grade	16
Fourth grade	22
Assistant surveyors:	
First grade	23
Second grade	25
Third grade	27
Fourth grade	29
Total	225

A large number of native assistants, printers, laborers, &c., are also employed.

GENERAL PLANS.

The geodetic survey, which is called the Great Trigonometrical Survey, was commenced at the beginning of the present century, the first fieldwork being done in 1802. The plan of the work has been from the outset to execute a series of meridional chains or belts of simple figures, from one to three degrees apart, connected by comparatively few cross-chains in the direction of parallels of latitude. The spaces between the chains of primary triangulation are filled by less refined and less expensive triangulation. All this work has been executed with geodetic refinement, and is now practically complete.

Topographic surveys under a systematic plan began soon after the inception of the geodetic survey. This work is based upon triangulation. In its progress the geodetic triangulation was used wherever it had been executed in time for the work; but where it was not available, a topographic triangulation was made of only sufficient refinement for topographic purposes. The work has been carried on almost entirely with the plane-table. The early field-work was upon a small scale, scarcely suitable for publication on a scale of 4 miles to the inch, but for a number of years past the field-work has been executed on a scale of 1 mile to the inch in a much more refined manner. The early work has been revised by new surveys. The great map of India, or, as it is termed, the Great Atlas of India, is on the scale of 4 miles to the inch.

The cadastral surveys are known as the Revenue Surveys. Prior to 1822 they were chiefly executed by natives in a very rough and crude way, and there was little work done of an accurate character until 1847. Since that date accurate work has been executed with great rapidity. All of the cadastral work is based upon the geodetic points established by the grand triangulation.

The surveying for village maps is carried on by the plane-table method, but upon a basis formed by carrying traverses with the theodolite and chain around the boundaries of the villages instead of using a basis of triangulation. The usual details are represented on the maps, and the land is classed as cultivated, fallow, or waste, at the time of the survey.

The survey for maps on a sixteen-inch scale (1:3960) is the proper cadastral survey. The work is done entirely by traverse methods.

COST.

As the result of ten years' experience, from 1867 to 1877, the topographic work costs as follows:

On the survey executed on a scale of 1 mile to the inch, and which is published on 4 miles to the inch, the average output per man, per month, was 58.8 square miles. The total cost averaged between $10 and $11 per square mile.

For the same time the output per man in the cadastral surveys of 4 inches to the mile is about 14 square miles per month, and the total cost averaged $26.50 per square mile.

On the cadastral scale of 16 inches to the mile, the average output per man is a little less than 1 square mile per month. The average cost is $82 per square mile.

GERMANY.

ADMINISTRATION.

In Germany geodesy, including the primary triangulation, astronomic determinations of latitude, azimuth, and longitude, levelings of precision, testing of standard measures, &c., is done by the Geodetic Institute, a civil organization, under the Department of Religion, Education, and Public Health. This work is executed under the general supervision of the International Association, and follows the topographic triangulation explained hereafter.

Topography, with a triangulation for topographic purposes, is executed by the General Staff of the Army. The general staff has control of the work, but line officers may be detailed to execute the work in the field under their direction, and many civil assistants are employed.

The General Staff of the German Government is a peculiar organization. Entrance thereto is obtained in the following manner: First, candidates must be graduates of the War Academy; second, after graduating and serving with regiments a number of those of the highest standing are selected and assigned for six months to another arm of the service; third, if they acquit themselves well they are then summoned to Berlin and assigned to general staff duty on probation for two years; fourth, at the end of this probationary period they are returned to their regiments, and shortly after those who are regarded as qualified are named captains of the staff, and then serve three years as staff officers. Then they must go back to the line, and are required to command a company, battery, or squadron for one year. At the end of this time those who are still considered to be worthy of promotion and permanent position on the staff are promoted to majorities. From this point promotion is by seniority to the colonelcies, and all subsequent promotions are by selection for qualification. The operations of the general staff are entirely independent of the Minister of War, and are directed by the Chief of Staff, who is the Emperor's chief aid.

But the general staff consists of two divisions: The main division, as described above, and an accessory division. This accessory division is chiefly charged with scientific duties, and is entirely separate, as regards promotion, from the general staff. The officers composing it are in the main borne as supernumeraries of the general staff. But graduation from the War Academy and military service is not a necessary qualification to a position in the accessory division; that is, the accessory division is a body of men selected from the army or from civil life for their scientific qualifications, and given rank and pay affiliated to the rank and pay of the staff corps.

GENERAL PLANS.

Since the organization of the present German Empire it has been engaged in revising and unifying the older work of the states that were consolidated. The staff organization above described, which executes the topography, is divided into three branches: The first for triangulation, the second for topography, and the third for cartography. The new map of the German Empire is to be engraved on a scale of 1–100,000, and the plans are made to have it completed by the year 1900. It will be composed of six hundred and seventy-four sheets.

The twenty-six states that were consolidated to constitute the present German Empire are as follows: Prussia, Bavaria, Würtemberg, Saxony, Baden, Mecklenburg-Schwerin, Hesse, Oldenburg, Brunswick, Saxe-Weimer-Eisenach, Mecklenburg-Strelitz, Saxe-Meiningen-Hildburghausen, Anhalt, Saxe-Coburg-Gotha, Saxe-Altenburg, Waldeck, Lippe, Schwarzburg-Rudolstadt, Schwarzburg-Sondershausen, Reuss-Schleitz, Schaumburg-Lippe, Reuss-Greitz, Hamburg, Lubeck, Bremen, and Alsace-Lorraine. It would extend this statement too greatly to explain the organization and plans of each one of these states, but the following states, namely, Baden, Bavaria, Prussia, Saxony, and Würtemberg, and perhaps others, are completing work begun anterior to the consolidation.

A short account of what each of these states is doing may be interesting and instructive. In Baden a new map was commenced in 1874 on a scale of 1–25,000, with contour lines having vertical intervals of 10 meters, about 33 feet. The work is mainly a revision and correction of earlier surveys, and costs about 80,000 florins ($32,800), or $5.65 per square mile. Bavaria completed her map in 112 sheets on a scale of 1–50,000 in 1868, but is revising the map, and now publishes it by photolithographing the plane-table sheets on a scale of 1–25,000 as the work progresses. The whole will eventually be re-engraved on copper on a scale of 1–50,000. Prussia introduced new and important methods into her topographic survey in 1849. The plane-table sheets are now published on a scale of 1–25,000, with contours varying from 5 to 25 feet, as may be best adapted to the country. The publication of these sheets began in 1868. The topography of Bavaria is reduced for final publication to a scale of 1–100,000, the scale of the general map of Prussia, and is nearly complete. It is engraved on copper with contour lines having vertical intervals of 5 meters, about 16 feet. In executing the work the triangulation is brought down to a low order; that is, the triangles are subdivided until one point in each two square (English) miles is determined, and a cut stone is placed at each point thus determined. The cost of this minute triangulation, brought down to the lowest degree for cadastral purposes, together with the cost of topographic work, engraving and publication, is stated to be about $44 per square mile.

In Saxony the general topographic survey began in 1780, and was completed in 1806, on a scale of 1-12,000, the area of the kingdom being 5,600 square miles. A topographic map was issued, 1837 to 1860, in twenty-two sheets, on a scale of 1–57,600. In 1860 it was determined to construct a new map on a scale of 1–100,000, and it was completed in ten years. This map was published in two editions, one with hill topography and one without.

Würtemberg has a map on a scale of 1–50,000, of which a new edition is now in progress.

Alsace-Lorraine has the old Staff map of France on a scale of 1–80,000.

AUSTRO-HUNGARY.

ADMINISTRATION.

About 1868, Austria and Hungary entered into the present mutual offensive and defensive compact, by which each country preserves its own autonomy in certain respects and has its own legislative bodies and executive departments. The United Realm has three executive departments, namely: (1) a department of foreign affairs, (2) a department of war, (3) a department of finance. Austria pays 70 and Hungary 30 per cent. of the taxes necessary for the support of these departments. Under the department for national defense there is an establishment known as the Military Geographical Institute. This was thoroughly organized in 1869 by imperial decree, and reorganized April 17, 1881. The *personnel* of the institute consists of staff officers, line officers, civilian assistants, non-commissioned officers, soldiers, and contract workmen. The head of the institute and the heads of the various divisions are staff officers. The staff has entire charge of the scientific part of the survey, but the line officers are detailed to aid in the work. The system for selecting staff officers is somewhat analogous to the system in Germany, under which young officers of great ability may be rapidly promoted to the higher military and scientific positions. But in Austria those officers who belong to the Military Geographical Institute are selected from private life by competitive examination, and receive their promotions in a special category of their own, independent of the other officers of the staff. This particular corps of officers, therefore, has a constitution only affiliated to the military organization. Line officers are detailed from the army and placed in this organization to execute work under the direction of the staff officers, and a school is established in which these line officers are trained by lectures, examinations, and field experience. There are sixteen sections in the institute, over each of which a staff officer, ranking as captain, presides.

GENERAL PLANS.

In the early history of Austria and Hungary, maps were constructed for different areas, and at different times, on different plans, but there was no unified system. The Seven Years' War, in the eighteenth century, developed a need of better maps and topographic surveying. Under the influence of the Emperor Joseph II a complete map of the empire was made before the end of the eighteenth century. In 1792 a decree of the Emperor Francis II was issued, by the terms of which a new survey was ordered to be executed upon a uniform and scientific plan. Notwithstanding intervention by war, the work was persistently carried on. A net-work of triangles was gradually extended over the whole empire for topographic purposes, and was followed by the making of topographic maps with the highest degree of accuracy known at that time. These maps were executed on a field-scale of 1–28,800, and in their preparation many cadastral maps were used. The cadastral maps were usually on a scale of 1–2,880; the topographic maps were ultimately published on a scale of 1–144,000. This was the condition of map-making in the empire down to about 1850, when a geological survey was instituted, and questions of map-making were again revived. At this time a geographic commission was constituted, charged with the duty of perfecting a plan for systematic surveys and the publication of a map for the entire empire, suited to industrial and scientific wants. This commission was composed of persons connected with various departments of the Government. Among them was the director of the Military Geographic Institute, the chief of triangulation, the director of the cadastral survey, the director of roads and water-ways, the chief commissioner of railways, the minister of public works, and the director of the geological survey.

The plan submitted and adopted was to make a topographic map of the entire country, the field-work to be on a scale of 1–25,000, and the map to be published on a scale of 1–75,000. The old topographic methods of representation by hachures, &c., were abandoned, and the new map was to be constructed with contours. It was also decided that each sheet should represent one degree of latitude and one degree of longitude. The maps are etched on copper, and a large part of the work is now complete.

A general chart of the realm, in thirty sheets, with a scale of 1–750,000, printed in four colors, has been completed. A hypsometric map of the realm has been published by the Department of Public Instruction.

Cadastral maps are constructed on a scale of 1–2,880 and seem not to be published.

SPAIN.

ADMINISTRATION.

Geographic work in Spain is under civil administration. The organization under which it is conducted is known as the Bureau of Geography and Statistics; but there is a topographic brigade of the corps of engineers of the army which executes surveys for purposes of military defense and the construction of fortifications. The bureau above mentioned is under the supervision of the Ministerio de Fomento, a ministry partly comparable to the Department of the Interior of the United States, and contains numerous semi-independent bureaus. The Bureau of Agriculture, Manufactures, and Commerce includes the direction of the corps of mining engineers, civil engineers, forestry, and public works. The Bureau of Public Instruction is concerned with schools, colleges, universities, medical and scientific academies and societies, libraries, museums, botanical gardens, fine arts, and astronomical observatories. The Geographical and Statistical Institute is the successor of the various civil bodies and commissions which had previously had charge of geographic and geodetic surveys in the widest sense of the words. All of these commissions were attached to the Bureau of Statistics by royal decree of November 3, 1856. Geographic works formerly under the War Department were placed under this general direction in 1873. The institute has entire charge of all geographic and geodetic surveys and publications of maps, and is immediately dependent on the Ministerio de Fomento as a special bureau. Officers of the topographic brigade of the army, and of the corps of mining engineers may be detailed for work under the bureau. The bureau maintains a school for the purpose of instructing military officers in geographic surveying. A trained corps of topographers has been formed under the direction of the institute, and many military officers receive instruction therein to fit them for performing work on the geodetic and secondary triangulation and on the preparation of the map. The work of the geographic division of the institute consists of geodesy and topography. Geodesy and topography are executed in each of the districts into which the kingdom is divided by a corps of civil assistants, directed by an officer generally detailed as chief of the work of that district from the topographical brigade of the army.

GENERAL PLANS.

The triangulation of Spain is divided into two series of works, one consisting of a strictly geodetic net-work of the highest theoretic accuracy, observed with the most perfect instruments, and serving as a fundamental basis not only for geographic work of other kinds, but for theoretic inquiries in regard to the figure of the earth and other problems of higher geodesy. It consists of ten series of fundamental triangles running north and south and east and west, connected with the African mainland by reciprocal observations with high mountain stations as vertices. These combine into series of quadrilaterals.

The second series, which serves as a basis for the topographic maps, comprises triangles of the second and third orders. These smaller figures are connected with the primary stations to insure accuracy, and may be extended in local or irregular net-works according to the demands of the time and place, but will eventually be connected with the geodetic work proper, and so cover the entire country with a net-work based upon accurately determined points, whose absolute latitudes, longitudes, and bearings from each other are known. The topographic work is divided into two classes, planimetry and hypsometry, or measurements of areas and of heights. The first determines the boundaries of political divisions and of cultivated areas exceeding 10 hectares (24.7 acres), the courses of rivers, canals, roads, and railroads, the arrangement and location of artificial structures, houses, and other buildings, the outlines of valleys—all on a field-scale of 1–25,000. All points of any consequence are determined by triangulation and connected with stations of the secondary or primary systems of triangulation.

The second class of topographic work includes lines of leveling of great precision, having as a bench-mark the mean height of the Mediterranean at Alicante. All the stations of the primary triangulation are determined in altitude by this method. Secondary details of topography necessary for the construction of the map are included in this class, together with such details as to the towns as are absolutely required for that purpose, but not in excess of those requirements.

The topographic work, to a large extent, has preceded the geodetic work, as explained above, having a triangulation of its own of a second and third order. The geodetic work is now being pushed forward with great rapidity.

MAPS OF THE GEOGRAPHICAL INSTITUTE.

1. The topographic map of Spain, surveyed on a scale of 1–25,000 and published on a scale of 1–50,000 will comprise 1,080 sheets, engraved on stone and printed in colors. Each sheet is to contain 20 minutes of longitude and 10 minutes of latitude. Contours printed in brown represent differences in altitude of 20 meters (about 66 feet). Water is printed in blue; gardens, orchards, and forests, green; main roads, buildings, and other structures, red; railroads, boundaries of political divisions (and of cultivated lands exceeding 10 hectares, or 24.7 acres, in one area), and nomenclature, black. The portion of the terrestrial surface represented on each sheet is treated as a plane, without taking the curvature of the earth into consideration. In 1881 fourteen sheets of that map had been issued. The publication was begun in 1875.
2. The military and road map of Spain, begun in 1865, and of which twenty sheets had been issued in 1881, is printed in colors, on a scale of 1–500,000, and accompanied by eight books of itineraries. It contains no topography.
3. Besides these, an atlas of Spain for popular use is to be issued in chromolithography, in two scales, 1–100,000 and 1–200,000. No information is at hand in regard to its state of progress.

CADASTRAL SURVEYS.

Cadastral surveys have been executed in special localities, such as the vicinity of Madrid, Seville, Carthagena, Valladolid, &c. These surveys are made at the expense of the municipalities, which pay for everything except the salaries of the corps engaged on the work. The scale and method of publication of the maps are not stated in the works of reference accessible, and probably vary with circumstances.

CONSTRUCTIVE ENGINEERS.

The Corps of Civil Engineers is under the Bureau of Agriculture, Manufactures, and Commerce. It is concerned with railways, roads, canals, rivers, ports, light-houses, and telegraphs. The heads of the various sections form a constructive body on the question of all public works, and are under the general direction of the Ministerio de Fomento. A school of civil engineering is affiliated to the bureau. Its surveys are local, and relate to special works of construction, harbor improvements, and the navigation of internal water-ways, &c. The chief of the corps was, in 1871, charged with the preparation of an edition of the general map of Spain which should be on a reduced scale and cheaper than the standard map of the Geological Institute, and therefore better adapted to popular use.

PORTUGAL.

All of the surveys in this country are and have been under civil administration, but officers from all services of the army, as well as engineer soldiers, are detailed to the work and are employed with civilians. Little progress was made in topographic work until 1852, when a Government department was established under the title of the Ministry of Public Works. One of its bureaus was entitled the Department of Geographic Works, and took charge of triangulation, topography, and hydrography.

GENERAL PLANS.

Prior to the organization of the Ministry of Public Works triangulation was begun in 1779, discontinued in 1796, resumed in 1835, discontinued in 1839, and resumed in 1843. Since the new organization the successive modifications of the plans of work are instructive. It was at first proposed to execute a geodetic triangulation and follow it with a survey on a scale of 1–10,000. But this plan was soon abandoned; the geodetic work, however, was continued, and a topographic survey proper was instituted on a scale of 1–100,000, with a triangulation of its own sufficient only for topographic work; but on account of the urgent need of a map of the country, the work on a scale of 1–100,000 was temporarily abandoned, and a map was constructed on a scale of 1–500,000, and the geodetic triangulation was also temporarily stopped. In 1876, the map on a scale of 1–500,000 having been constructed, work on the topographic map proper on a scale of 1–100,000 was resumed. Work on a scale of 1–10,000 has been entirely abandoned, but a cadastral survey has been established on a scale of 1–2,500 for some districts, and a scale of 1–5,000 for other districts. The appropriations now made for geographic work are unknown; for the fiscal year 1875–'76 the appropriation was $62,466.30.

ITALY.

ADMINISTRATION.

Geographic work in Italy up to the organization of the Geodetic Association was of greatly varied character. Changes of government from time to time have effected changes in the geographic organization and methods. The history of the many plans and changes would require too great space for their explanation here. Under the present government the geodetic and topographic surveys are conducted under the military department of the war office. This department has a "Board of Control," and embraces four divisions, the first of which includes geodesy, astronomy, mathematics, and the selection and construction of instruments; the second includes topography, and the custody of instruments, maps, and records; the third includes drawing and engraving; and the fourth photography, the preparation of casts, and bookbinding.

GENERAL PLANS.

The following is a summary of the general maps of portions of Italy made prior to 1860:

The map of the provinces and the kingdom of Sardinia, on a scale of 1–50,000.

The map of the island of Sardinia, on a scale of 1–250,000.

The map of Venetia, Lombardy, the duchy of Parma and Modena, and Central Italy, on a scale of 1–86,400.

The map of Tuscany, on a scale of 1–200,000.

The map of the kingdom of Naples, on a scale of 1–114,942.

The map of the island of Sicily, on a scale of 1–260,000.

All these maps were based upon triangulation of sufficient accuracy for the requirements of the scale, but not of sufficient accuracy for geodesy. In 1861 the Italian Government decided to construct a map of the Neapolitan provinces in the island of Sicily, but had barely commenced operations when the movement among the European governments for a unified system of geodetic work was commenced, and the work was modified in accordance with that plan. Geodetic work has been carried on since 1865, in accordance with the plans of the International Commission. Topographic work is now being carried on actively by the Topographical Military Institute, based upon the refined geodetic triangulation. The map is constructed on a scale of 1–50,000.

SWEDEN.

ADMINISTRATION.

Geographic work properly began in Sweden in 1628, under the geographer Bure, under the department which corresponds to the Interior Department in the United States. The work executed was both topographic and cadastral. In 1859 a special bureau was established for the preparation of maps and illustrations of the natural resources of the country, and general maps of Sweden were constructed. For a number of years special military maps were constructed by the staff of the army. In 1873 the general work was completed and the office closed, and all topographic work since that time has been executed under the war department.

GENERAL PLANS.

The triangulation of Sweden was executed for topographic purposes only, and was therefore not of geodetic refinement.

The topographic survey, completed in 1873, was based on a triangulation, as mentioned above, and field maps were constructed for the southern portion of the country on a scale of 1–20,000, and for the northern portion of the country on a scale of 1–50,000. Under the same department maps have been prepared on the following scales: The general atlas of Sweden is published on the scale of 1–100,000, and maps of the provinces have been published on a scale of 1–200,000. In addition to this, certain maps of special localities have been made on a scales of 1–20,000 and 1–10,000.

The general land office, as now organized in Sweden, corresponds to the cadastral survey organization of other states of Europe. It has possession of the "land register;" and a record of the valuation of all of the real estate of the country is kept by the "College of the Treasury Department." The cadastral charts made by the land office are deposited, one copy in the "College of the Treasury Department," and one in each county. The cadastral maps are based upon a triangulation, and are constructed in such a manner that much valuable material can be compiled from them for the general topographic map of the country. The cadastral maps are not published. They are usually made on a scale of 1–4,000; but in the more densely populated districts a scale of 1–2,000 is used, and in districts sparsely populated a scale of 1–8,000 is authorized. This office has charge of the redistribution of lands, which may need a little explanation. The peasant holdings, originally small, had from generation to generation been subdivided through inheritance; that is, the father on dying left his property to be divided among his children. At the same time a process of integration was in progress due to the combining of properties by marriage. After division and integration had gone on in this manner for many generations, a single holding would often be composed of tens or scores of minute tracts of land, often less than a quarter of an acre, scattered at inconvenient distances. A similar condition of affairs existed in most of the states of Europe, and for many years a redistribution of these holdings has been in progress. For this purpose a careful survey of a parish or some small district of country is made; all the parcels are valued, the whole district is redivided, roads laid out, a new plan of settlement instituted, and the new holdings are divided among the people in proportions and values corresponidng to their former scattered holdings.

COST.

The cost of surveys cannot be obtained, from the fact that a part of the expense was borne by the General Government, a part by municipal authorities, and the larger part by individuals. The expenses for topographic work paid by the General Government, and not including the pay of officers and men, from 1812 to 1874, at the time when the general topographic bureau was closed, was as follows:

Triangulation	$37,000
Astronomic work	3,500
Topographic field-work	163,000
Engraving, &c. (map of Sweden)	64,000
Engraving, &c. (Lân maps)	25,000
Office-work	25,000
Traveling for inspection	7,000
Salaries to civilian assistants	18,000
Rent	12,000
Sundries	65,500
Total	420,000

The corps of land surveyors under the orders of the director-general at the close of 1876 (the latest information at hand on this point), was 680 officers and employés, distributed in the various counties. In the same year landed proprietors paid for redistribution the sum of $201,000, which did not include payments to officers of the central bureau, who were paid by the General Government, $111,000; so that the expense of redistribution for that year was $312,000.

NORWAY.

ADMINISTRATION.

In the last part of the eighteenth and early part of the nineteenth centuries irregular and intermittent topographic surveys were made in Norway. Subsequently all such surveys were placed under the war department for the purpose of establishing a unified control. By royal decree of June 18, 1884, all of the topographic, geodetic, and cadastral surveys were placed under the Department of the Interior, and the Norwegian Geographic Commission was organized. This commission is composed of the chief of the general staff of the army, who presides, the director of the agricultural department, the director of forestry, the director of the bureau of navigation of the navy department, the director of the Observatory of Christiana, and certain professors of the University of Christiana. A lieutenant of the general staff of the army is detailed to act as secretary of the commission. Officers of the army and navy, and of the scientific institutions of the country, combine to carry on the work.

The work of the commission includes geodesy, topography, cadastral surveying, and hydrography. Since the organization of the International Association, the geodesy has been in charge of a body of civilians, who are members of the Geographic Commission, and includes the director of the observatory and professors of the university.

GENERAL PLANS.

Prior to the establishment of the international association the triangulation of Norway was designed for topographic purposes. The general topographic maps are published on a scale of 1-100,000, and are lithographed in colors, with contours having 100 feet vertical intervals. Special districts of greater importance are surveyed on a scale of 1-50,000, and other districts of minor importance on a scale of 1-200,000. Subsidiary maps are prepared: one on a scale of 1-400,000, lithographed in colors, with contours; and a sketch map of Norway on a scale of 1-1,500,000. The general topographic map above mentioned is in sheets that represent 28 by 21 miles, and each sheet is named from its principal town. The cadastral surveys are on a scale of 1-8,000. Sometimes general topographic maps are made of special districts, and cadastral surveys of the larger towns they contain are placed on the same sheets. The hydrographic charts are engraved on copper, and are of the highest degree of excellence. Special charts of fishing banks are published, with gradations of depth indicated in colors for the use of the more illiterate fishermen.

COST.

The climate of Norway is humid and the skies are often overcast for a great length of time, so that triangulation and topographic work are executed with great difficulty. The favorable season never exceeds three months. It is estimated that on an average one surveyor is able to execute per annum about 350 square miles on a scale of 1-50,000, or 600 square miles on a scale of 1-100,000.

Of late years the annual appropriation has been about $50,000 for topographic work, and $2,500 for the geodetic work of the International Commission. This does not include the salaries of the permanent members of the corps, but only the pay of field expenses and temporary employés.

RUSSIA.

ADMINISTRATION.

Geodetic, topographic, and cadastral surveys are prosecuted in Russia under the topographic department of the general staff. The chief of the general staff is the second officer of the army under the Emperor. Entrance to the general staff is secured by training in a series of schools of different grades established throughout the empire, and advancements in the schools and promotions in the staff are for merit, in the main determined by examinations. The schools are open to all pupils who are able to pass the examinations. The general staff has a military organization.

In the earlier history of geographic work, such work was under military topographers, subordinated to the war ministry, but in 1866 it was completely reorganized and placed under the general staff, as above described.

GENERAL PLANS.

Up to 1884 geographic work was done under a variety of methods and on various scales, but in 1884 a general council of the authorities engaged in such surveys was held for the purpose of deciding upon a uniform system of conducting the details of such work, for which the Government annually expends about a million dollars. This council, embracing Messrs. Struve, Tillo, Faddeieff, Pustchin, and several members of the Imperial Geographical Society, met and elaborated a plan which was submitted to the authorities for approval. The new Russian system has not been made public; the previous work will be briefly characterized.

GEODETIC WORK.

Russia has executed several important geodetic works, notably Struve's arc of meridian from the North Sea to the Danube, and her part of the great arc of the parallel of 52°, extending from Valentia, in Ireland, to Orsk, in Russia. Both of these were executed with great refinement. She has also made primary triangulations covering large areas in Western Russia, the valleys of the Volga and the Don, and the region of the Caucasus. This latter work was not of geodetic order, but only sufficiently refined for topographic purposes.

TOPOGRAPHIC SURVEYS.

The great imperial survey of Western European Russia was begun in 1819. Each government or province was to be independently surveyed and covered with a net of primary triangulation, so arranged as to give two or three points on each sheet of the topographic work, as a basis for secondary triangulation. Surveys carried out in pursuance of this plan were of different degrees of elaboration, varying from instrumental triangulation and methods of precision to surveys only in part instrumental, and others of pure reconnaissance. The plane-table sheets covered areas of about 12 miles square, and the field-work was executed on a scale of 1–21,000 in most cases. Similar surveys were made in South Russia, Western Siberia, Finland, Orenburg, and Bessarabia. Rough reconnoissance work was done in Moldavia, Wallachia, and Bulgaria. Within the last few years work of a higher character has been carried on, especially on the frontiers of China, Persia, and Afghanistan, the latter in connection with an international commission, in which Great Britain took part. This was practically a boundary survey. The survey of much of the interior of European Russia was based on points astronomically determined. Chained lines were run from one astronomical station to another along open roads. Three sides of an astronomical triangle were thus surveyed, with intersections on laterally situated objects. But these sides averaged 50 versts in length (33 miles), without any intermediate standard points. Accordingly other lines were run in a similar manner from the stations to the middles of the lines on the opposite sides of the triangles. The determination of altitudes in topographic work appears to have been introduced in 1861, in the surveys of Kazan and Kostroma. Since then many lines of levels have been run, and in 1884 General Tillo published, under the auspices of the department of public works, a hypsometric map of European Russia containing 18,000 points of which the altitude had been determined, 17,400 by spirit leveling and trigonometric methods and 600 by barometric methods. Lines of levels have been run between the Baltic and Black seas, and between the Black Sea and the Caspian.

SCALES.

All topographic work of the best class in Russia is executed in the field on a scale of 1–21,000, and published on a scale of 1–126,000.

The cost of topographic work in Russia varies from $2.50 to $6 per square mile.

CADASTRAL SURVEYS.

The cadastral surveys of Russia are executed on a scale of 1–8,400. The extent to which this work has been carried on, and its cost, are unknown.

SWITZERLAND.

ADMINISTRATION.

The geodetic and topographic work of Switzerland has been conducted for many years by the chief of staff of the war department of the confederation, though important work has been done by the several cantons.

GENERAL PLANS.

The geodetic work was completed many years ago, and appears to have been used for no other purpose than as a basis for topographic maps. Since the organization of the International Geodetic Association, this geodetic work has been undergoing revision by refined methods for geodetic purposes.

A topographic map was long ago constructed of Switzerland, and is known as the "Dufour map." At the time of its completion it was considered a model of topographic work for the world. The scale was 1–100,000. It was engraved in hachures, and heights were indicated by figures placed on the more prominent elevations. The sheets of this map were 23 inches in latitude and 29 inches in longitude.

Since the construction of the Dufour map topographic surveying has been revolutionized, and a new survey has been organized. This work is at present carried on by what is known as the topographic bureau, under the general staff. The bureau consists of a chief, at present a colonel of the staff, one clerk, and two topographers. The field-work is done by contract. The contract prices are as follows: Topography executed on a scale of 1–25,000, from $16 to $18 per square mile; topography on 1–50,000, from $8 to $9 per square mile.

Cadastral surveys are executed by the cantons; city maps on a scale of 1–200, village maps on a scale of 1–500, cultivated lands on a scale of 1–1,000, wood-lands on a scale of 1–2,000.

BELGIUM.

ADMINISTRATION.

The geodetic and topographic surveys of Belgium are conducted under the war department, and staff officers have had charge of the work since its inception. The astronomic work, however, has been done under the direction of J. C. Houzeau, a member of the Brussels Academy.

GENERAL PLANS.

Topographic surveys began at the request of the French Government for maps of certain battle-fields, but they were extended so as to embrace the entire area of the kingdom. All of the triangulation has been of geodetic refinement. A map of Belgium has been constructed on a scale of 1–20,000, with contours at vertical intervals of 1 meter (3.28 feet). The area of Belgium is 11,373 square miles; the population 5,619,000, and the valuation of property nearly $5,000,000,000. These facts relating to area, population, and valuation of property fully explain the origin and reasons for constructing a general map of the country on a scale so large and at such a great expense. The map is divided into 450 sheets, each 23½x16 inches. Another topographic map is constructed on a scale of 1–40,000, with contours having vertical intervals of 5 meters (about 16 feet). Subsidiary charts are constructed as follows: One on a scale of 1–160,000, showing routes and lines of communication—a map of public highways. Second, a hypsometric map on the same scale and constructed in the same manner as the one above, with the addition of elevations above the sea-level, indicated by numbers placed on the crests of hills and mountains and in the depressions of valleys, &c. A cadastral survey has been executed on a scale of 1–2,500.

DENMARK.

ADMINISTRATION.

The geodetic work in Denmark dates from 1765. It was first pursued for cartographic purposes only; but in the early part of the present century it was executed for geodetic purposes, and funds for prosecuting the work were placed at the disposal of the professor of astronomy of Copenhagen. Under his direction the work was carried on from 1816 until his death, in 1850. In 1853 a special directorship of geodetic work under the ministry of finance was instituted. Since then the work has been carried on by C. G. Andrae, state counselor and director of the survey.

The topographic work is executed by the topographic bureau of the general staff of the army, and the head of the bureau is chief of staff. The work of the bureau is divided between two classes of officers, commissioned and non-commissioned. Entrance into the topographic corps is as follows: Boys enter the military academy at the age of fourteen. On graduating they are assigned for duty in the infantry for one year. At the expiration of a year they are sent to the military high school, where they study for four years. At the end of the four years the leading graduates are appointed as lieutenants in the staff. They are then assigned to duty for one year in the cavalry, and then one year in the artillery. At the end of this time, those who pass a rigid examination are confirmed as members of the staff of the army. A subsidiary topographic bureau, called the guide corps, is selected from the non-commissioned officers of the army for special fitness. They are engaged on the topographic corps for twenty-five years, and then are entitled to be transferred to civil service.

GENERAL PLANS.

Topographic maps of Denmark and Schleswig are published on a scale of 1–80,000, with contour lines having vertical intervals of 10 feet. The map of Jutland is on a scale of 1–40,000, with contour lines having vertical intervals of 10 feet. When complete, the map will comprise 81 sheets for Denmark, including Schleswig, and 131 for Jutland. The work is still in progress. The map is engraved on copper.

CADASTRAL SURVEYS.

The cadastral surveys were completed many years ago, but the maps are revised and corrected from time to time. They are made on a scale of 1–4,000. It seems they are not published.

THE INTERNATIONAL GEODETIC ASSOCIATION OF EUROPE.

The International Geodetic Association of Europe, having for its object a minute investigation of the size and shape of the earth, was organized in 1862. The idea of combining and unifying in one grand system the geodetic work carried on by the separate European States appears to have originated with General Baeyer, director of the Prussian Geodetic Institute.

The first step toward the formation of a general conference of the states was a meeting, held in 1862, at Berlin, at which delegates from Austria, Saxony, and Prussia met under the presidency of General Baeyer. To the call issued at this time nearly every country made a favorable response. The first general conference of the association thus formed was held in Berlin in 1864. The questions considered may be stated under three heads, to wit:

I. *Questions of administration.*

(1) On the form, extent, and publication of reports on the works of the different countries.

(2) On the formation of a central bureau for the execution of geodetic work in Europe.

(3) On the formation of an international commission for the critical examination of existing work.

II. *Questions of astronomy and physics.*

(1) On the adoption of methods of observation for determinations of latitudes, azimuths, and longitudes.

(2) On new determinations of fundamental stars.

(3) On determinations of the intensity of gravity.

(4) On measurements of magnetic forces.

(5) On systematic investigations of plumb-line deflections at all vertices of primary triangles.

III. *Questions of geodesy.*

(1) On the systemization of standards of length.

(2) On the adjustment of discrepancies in length and azimuth shown at the junction of two or more systems of triangles on a common side.

(3) On the calculation of the polar co-ordinates of points determined in the astronomico-geodetic networks.

(4) On the systemization of absolute heights.

(5) On the junction of chains of triangles of neighboring states for the construction of a general map of Europe for the use of the association.

At the conference in 1864 the association decided to establish a permanent commission and a central bureau. The permanent commission is composed of nine members of the association, elected by the association, and so arranged that once in three years four members retire and their places are filled by a new election. The central bureau, with its headquarters at Berlin, is the acting organ of the commission and the headquarters for the general transaction of business and the custody of the archives. Under the general management of the permanent commission, whose decisions are executed by the central bureau, the geodetic work of Europe is carried on.

There is yet another permanent commission under the general association, organized for the purpose of considering questions relating to standards of measure, and known as the International Bureau of Weights and Measures. It is composed of twelve members, selected by the delegates of the association. In connection with this there is also a central bureau for executive purposes, with headquarters at Paris. The present acting *personnel* consists of a director, two assistants, four aids, and two specialists. In accordance with the desire of the international association, this commission is charged specially with the construction of a number of prototype meters which are to be as nearly as possible of the same length as the Mètre des Archives of Paris. The lengths of these prototypes in terms of the Mètre des Archives and their coefficients of expansion are to be determined with the highest precision, to the end that each state represented in the association may have a standard referable at once to the common assumed standard, the Mètre des Archives.

To this commission is also intrusted the construction of kilograms, which, like the standard meters, are intercompared with the greatest precision, so that all may be referred to the same standard.

The principal operations which the international association has undertaken in its researches on the figure and dimensions of the earth may be summarized as follows:

I. *Measurements of arcs of meridians and parallels.*

The originally separate or imperfectly connected triangulations of the different states are to be joined and extended so as to form one vast system covering Europe and the African coast along the Mediterranean Sea. This system will be, in some of its parts, a complete net-work, and in some parts of a gridiron form. It will embrace within its area and be connected with no less than fifty-five fixed astronomical observatories. Besides these points, whose latitudes and longitudes are or will be known with the greatest precision, the latitudes and longitudes of numerous other points in the triangulation will be determined. The system when completed will furnish the lengths of numerous arcs of meridians in different longitudes and numerous arcs of parallels in different latitudes.

II. *Measurements of the intensity of gravity.*

Measures of this character are to be made especially in the vicinity of astronomical stations where a deflection of the plumb-line is known to exist or is suspected. An essential feature of this work will be the intercomparison of the pendulums used in the measures, in order that the measures may be comparable. An examination of the relief of the ground and the geological structure in the vicinity of pendulum stations will also be made, for the purpose of securing any data which may throw light on special local attractions.

III. *Precise determinations of elevations.*

Lines of precise levels are to be run in the various states, determining thus the relative heights of lakes, seas, and numerous points on the land. These lines of levels are to be carefully referred to permanent zeros or bench-marks, and these bench-marks are to be connected so that all the determinations of heights will be embraced in one system, which may then be adjusted for compensation of the small errors incident to the measurements. All points determined are to be permanently marked.

The following European states have been engaged in the work of the International Association during the years 1881–1883: Austro-Hungary, Baden, Bavaria, Belgium, Denmark, France, Hesse, Holland, Italy, Norway, Portugal, Prussia, Roumania, Russia, Saxony, Spain, Switzerland, Würtemberg.

The following states have signified their willingness to assist in the work of the association, but have not reported any work done during the period 1881–1883: England, Hanover, Grand Duchy Hesse, Mecklenburg, Saxe-Coburg-Gotha, Schleswig-Holstein, Sweden.

TABLE SHOWING THE TOPOGRAPHIC MAP-SYSTEMS OF VARIOUS FOREIGN COUNTRIES.

FRANCE.

Name of map.	Scale.	Size, of sheet.	Relief by—	Colors.	Reproduced by—
		Inches.			
STAFF MAP	$\frac{1}{80000}$	10 5½	Hachures	All in black	Copper engraving.
Do	$\frac{1}{320000}$		Contours and hachures.	Hachure ed. all in black	
Contour map	$\frac{1}{800000}$		Contours, int. 100 meters.		Lithography.
Map of Frontier Alps	$\frac{1}{80000}$		Contours, int. 20 meters.		Do.
Map of the Alps	$\frac{1}{320000}$				Do.
Railway maps	$\frac{1}{1600000}$ and $\frac{1}{800000}$			Railroads in various colors.	
Topographical maps	$\frac{1}{50000}$				Zincography.
Plans of towns	$\frac{1}{[illegible]00}$ and $\frac{1}{20000}$				
Maps of internal improvements.	$\frac{1}{100000}$ and $\frac{1}{1350000}$				

Table showing the topographic map-systems of various foreign countries—Continued.

GREAT BRITAIN.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
		Inches.			
GENERAL MAP GREAT BRITAIN:					
Old series	$\frac{1}{63360}$	24 × 36	Hachures		
New series	$\frac{1}{63360}$	*12 × 18 †18 × 24	Hachures and contours.		Copper engraving.
England and Wales	$\frac{1}{253440}$				

INDIA.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
INDIA ATLAS	$\frac{1}{15840}$ to $\frac{1}{253440}$	‡24 × 38 §12 × 19	Hachures	Black	Copper engraving.
General maps of India	$\frac{1}{2027520}$ and $\frac{1}{4055040}$				

*England and Ireland. †Scotland. ‡Old form. §New form.

GERMANY.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
MAP OF GERMAN EMPIRE	$\frac{1}{100000}$	11 × 13	Hachures	Water blue, boundaries red, rest black.	Copper engraving.
Alsace-Lorraine	$\frac{1}{80000}$	12 × 14	Hachures	All in black	Lithography.
Prussian states	$\frac{1}{25000}$	18 × 20	Contours, 5, 12½, 25 feet int.		Do.
Rhenish Prussia (Westphalia).	$\frac{1}{800000}$				
Hohenzollern	$\frac{1}{5000}$	17½ × 19½	Hachures and contours 50 feet apart.	Contours red, rest black.	Engraved.
Bavaria	$\frac{1}{50000}$ $\frac{1}{25000}$				Copper-engraving. Photo-lithography.
Hesse Cassel	$\frac{1}{25000}$		Contours, int. 75 feet.		Lithography.
Hesse Darmstadt	$\frac{1}{50000}$				Do.
Schleswig	$\frac{1}{120000}$				Copper engraving.
Holstein and Lauenburg	$\frac{1}{120000}$				Do.
Oldenburg	$\frac{1}{50000}$				Lithography.
Saxony	$\frac{1}{25000}$		Contours, int. 10 meters		
Do	$\frac{1}{100000}$		Hill shading and without.		
Würtemburg	$\frac{1}{25000}$		Contours, int. 5 meters.		Do.
Baden	$\frac{1}{25000}$		Contours, int. 10 meters.		
Military map of Prussia	$\frac{1}{12500}$ to $\frac{1}{80000}$				

AUSTRO-HUNGARY.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
AUSTRIAN STAFF MAP	$\frac{1}{75000}$	16 × 21	Hachures and contours at 20 meters.		Copper etching.
Uebersichts Karte	$\frac{1}{750000}$				

Table showing the topographic map-systems of various foreign countries—Continued.

SPAIN.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
TOPOGRAPHIC MAP	$\frac{1}{50000}$	*Inches.* 15 × 21	Contours, int. 20 meters.	Contours, brown; woods, meadows and swamps, green; water, blue; towns, roads, and walls, red.	Lithography.
Atlas of Spain	$\frac{1}{100000}$				Lithography.
Military and road map	$\frac{1}{130000}$		None		

PORTUGAL.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
MAP OF PORTUGAL	$\frac{1}{100000}$	20 × 31	Contours, 20 meters int.	All black	Engraved.
Do	$\frac{1}{500000}$				

ITALY.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
MAP OF ITALY	$\frac{1}{50000}$				Copper engraving.
Chorographic map of Italy	$\frac{1}{500000}$ and $\frac{1}{800000}$				Do.
Map of Italy	$\frac{1}{100000}$		Hachures and contours.		Heliography.

NORWAY.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
TOPOGRAPHIC MAP	$\frac{1}{100000}$	14 × 19	Contours, int. 100 feet.		Lithography.
"Amt" maps	$\frac{1}{200000}$				
General map of S. Norway	$\frac{1}{400000}$		Contours		
Geologic maps	$\frac{1}{100000}$				

SWEDEN.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
TOPOGRAPHIC MAP	$\frac{1}{100000}$ and $\frac{1}{50000}$	18 × 24	Hachures		Copper engraving.
"Län" maps	$\frac{1}{200000}$				Do.
General maps	$\frac{1}{1000000}$				
Special maps, city maps, &c.	$\frac{1}{100000}$ and $\frac{1}{20000}$				
Geologic maps	$\frac{1}{50000}$		None		

RUSSIA.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
EUROPEAN RUSSIA	$\frac{1}{126000}$				Copper engraving.
POLAND	$\frac{1}{126000}$				

Table showing the topographic map-systems of various foreign countries—Continued.

SWITZERLAND.

Name of map.	Scale.	Size of sheet.	Relief by—	Colors.	Reproduced by—
		Inches.			
TOPOGRAPHIC MAP	1/25000 and 1/50000	10 × 13	Contours, 10 and 30 meters int.	Contours, sienna; water, blue.	Copper engraving.
Dufour map	1/100000	23 × 29	Hachures	All black	Do.
General maps	1/250000 1/500000 and 1/1000000				
Railway map	1/250000				

BELGIUM.

MAP OF BELGIUM	1/20000	16 × 23½	Contours, int. 1 meter.		Photolithography.
OFFICIAL TOPOGRAPHIC MAP.	1/40000	19½ × 31	Contours, int. 5 meters.	Black	Lithography.
Special military map	1/20000 and 1/10000				Zincography.
Military map	1/160000		Contours, int. 20 meters.		
Special road map	1/160000		None		
Traveling maps	1/65000 and 1/600000				
Railway map	1/160000	23 × 36	Contours, int. 10 and 20 meters.	Roads and railways, red; contours, brown; water, blue.	
Geologic survey	1/20000				

DENMARK.

MAP OF DENMARK	1/80000		Contours, int. 10 feet.		Copper engraving.
Do.	1/40000	12 × 15	Contours, int. 10 feet.	All black	Do.
Map of Jutland	1/40000		Contours, int. 10 feet.		Do.
Map of Zeeland	1/160000		Contours, int. 31 feet.		

NETHERLANDS.

STAFF MAP	1/50000		Hachures		Lithography.
Wadter Stadts map	1/50000				Do.
Military map					Do.
River map	1/10000				
Topographical atlas	1/200000				
Telegraph and postal maps	1/250000				
Chief towns	1/20000				
Geological maps	1/200000		None		

GEOLOGIC SURVEYS OF FOREIGN COUNTRIES.

Before giving a sketch of the administration and plans of foreign geologic surveys, it seems better to make some remarks that will render the subject more generally intelligible.

In foreign countries geologic surveys had their origin much later than topographic surveys, and at a time when military organization for scientific work was waning. Geologic surveys have therefore been under civil scientific control even more thoroughly than geodetic surveys.

In very many cases they began as private enterprises subsidized by governments, and to a limited extent are still prosecuted on this plan. It will be remembered that the same plan has been adopted at different times by the Government of the United States. The King, Hayden, Powell, and other surveys were prosecuted under appropriations made by Congress to be expended by special persons, often specified in the acts, and there were no organic statutes instituting surveys until the establishment of the present Geological Survey. Some of the most important surveys throughout the world have been made upon this plan.

It is to be observed in the history of surveys that most countries have recognized the many and important relations existing between the science of geology and other departments of natural history, such as botany, zoölogy, ethnology, meteorology, and especially physical geography. This recognition of the scope of geologic work is exhibited in many ways, sometimes by including collateral investigations in the functions of the geologic survey, and sometimes by associating the geologic survey with other institutions having these special functions.

It is always recognized that a geologic survey must have a museum with its laboratories.

In most countries it is deemed important that the geologic survey should secure the services of unofficial scientific experts, and provision is often made for the employment of such persons. Sometimes the geologic survey is organized somewhat as a society, so as to include the learned men of the country who are specialists in the various branches of learning accessory to geologic research, and the members of such an association have a voice in the councils of the survey, and their contributions are published officially.

It is usually well recognized that to make a geologic survey properly subserve its purposes it must be preserved from falling into routine or perfunctory ways, and that its value depends upon the wisdom and efficiency of its methods for prosecuting *original research.*

It is invariably recognized that successful original research largely depends upon giving to the persons engaged in the work the honors and emoluments which accrue from scientific discovery. For this purpose all results of research are published under the name of the investigator, and he receives due credit for the same, and is held responsible for the accuracy of his facts and the wisdom of his conclusions—a plan that does not obtain under military organization.

It is usually recognized that every investigator and author should be subject to the rigid criticism of the scientific public.

It is usually recognized that appointments and promotions should be made for successful work, and not exclusively by seniority.

It is invariably recognized that the scientific operations of a geologic survey can only be prosecuted by men of the highest scientific attainments, and provision is made to secure the services of such men wherever they may be found. At the same time ample provision is made for the training of men who exhibit talent for research in the special lines of investigation needed for geologic work.

In the earlier history of geologic surveying in Europe the official surveys chiefly published geologic facts and economic geology, and relegated the discussion of philosophic geology to learned societies, which were usually more or less endowed by the several governments. This practice has steadily changed, until at the present time in all countries except England and Norway it is specially provided that the principles of geology shall be discussed, and that memoirs on such subjects shall be published, under official auspices.

Most countries distribute their official geologic publications gratuitously to government bureaus, learned societies, educational institutions, and to the geologic bureaus of other countries; but provide also for their sale at moderate rates.

It will be observed that few geologic surveys include topographic work, except for special purposes in important districts, from the fact that in most cases maps had previously been made for other uses and topographic organizations had already been instituted; but the geologic surveys have profoundly affected topographic methods, because geologists have demanded better maps than those previously constructed, and in some countries the geologists have been compelled to correct and improve topographic maps by instituting special surveys of revision. In those countries where topographic surveying has not preceded geologic surveying, geologic surveying includes topography.

The history of geologic surveying shows that it is considered advantageous for geologists to have in the field topographic maps constructed on a scale larger than that necessary for final publication. For this reason they sometimes use cadastral maps in the field and finally publish on topographic maps. Where topographic surveys are in progress it is customary to do field work upon a scale two or three times larger than that selected for publication. In cases like this the topographic field sheets are often reproduced by some cheap process, to be used by the geologists on the ground. This is the practice adopted in the United States Geological Survey.

It should be mentioned here that great diversity exists in the countries of the world in the methods used to represent geologic facts, by colors and other conventional signs. This use of diverse methods leads to much confusion and causes much unnecessary labor to those geologists whose broad studies require a knowledge of methods and results in all parts of the world. For several years an International Geological Congress has been held in various cities of Europe, the object of which is to unify systems of geologic cartography and representation. This movement originated at the Saratoga meeting of the American Association in 1879. The Director of the Geological Survey has taken part in its deliberations.

The United States Geological Survey, independent of its topographic work, has a larger and more elaborate organization and is more liberally endowed than that of any other country; but when the area to be surveyed is considered, together with the total value of the annual mining product, its rank is low as compared with European surveys. In topographic work the United States is far behind all nations of Europe, Russia alone excepted.

Geologic surveying was instituted in Europe much earlier than in America. For many years it has been carried on with vigor, so that in most European countries general geologic maps have been constructed, and the structural and areal geologies of such regions are already well known. To a great extent the officers and employés of the surveys are now engaged in making minute examinations and observing and recording details at present largely neglected in America. In the United States there are large districts of country the general geology of which is unknown, and until this general geology is discovered more minute surveys must be held in abeyance. Work such as we are now doing has been completed over a large part of Europe.

FRANCE.

ORIGIN AND HISTORY.

Louis XV, towards the close of his reign, commissioned Guetard and Monnet to make a mineralogic exploration of France, but their work was soon interrupted by the revolution of 1789. In 1794 the Republic charged the School of Mines and the Corps of Mining Engineers with the collection and digestion of documents relative to the geologic structure of France, and this led to the publication of a series of memoirs in the Journal des Mines, the Journal de Physique, and the Annales des Mines. In 1822 a plan was adopted for the preparation of a general geologic map from original data. The field work was performed by Dufrenoy and Élie de Beaumont, under the direction of Brochant de Villiers, professor of geology in the School of Mines, and was completed in 1834. The map, with one volumes of explanatory text, was published in 1841, a second volume appearing in 1848. This map was upon a small scale, and was necessarily imperfect. The need of more detailed work was immediately felt, and even before the map was published a circular was addressed to the prefects of departments, inviting them to co-operate with the engineers of mines to prepare detailed maps on a larger scale. This work was performed by a majority of the departments (fifty-nine out of a total of seventy-two), but its quality was not uniform, and for lack of a comprehensive plan it was so inharmonious as to render impossible the compilation of a satisfactory general map.

The existing survey was instituted in 1868, and has for its primary object the preparation of a detailed geologic map of France.

OFFICIAL RELATIONS.

The mines of France are chiefly owned by the state and leased to operators. The mining industry has been controlled for a long time by the government, and the School of Mines at Paris was originally instituted for the purpose of training and replenishing the corps of official mining engineers. It was natural, therefore, that general geology, when the demand for it arose, should be confided to the School of Mines and the Corps of Mining Engineers; and these institutions furnish the members of the board which controls the existing survey. It is known as the Special Commission of the Detailed Geologic Map of France (Commission Special de la Carte Géologique Detaillée de la France), and is under the Minister of Public Works. The executive head of the survey is a director, who has a deliberative voice in the commission. Its offices and collections are at the School of Mines, and the school is charged with the duty of performing its chemic work.

PLANS AND METHODS.

The geologic survey executes no general topographic work, but uses the atlas sheets known as the Staff Map. These are on the scale of 1–80,000, and represent France and Corsica in two hundred and sixty-seven sheets. Upon them are plotted, not only the outcrops of the formations, but a great variety of information in regard to rock texture, rock structure, ores, mines, and quarries. The information is embodied in an elaborate system of conventional signs, numbering more than one thousand, and rendering the maps almost valueless, except to experts.

PERSONNEL.

The members of the geologic corps are largely selected from the Corps of Mining Engineers, and these are graduated from the School of Mines and the Polytechnic School. They are divided into four grades, including nine classes. Nomination for promotion from grade to grade is made by the Minister of Public Works. Promotions from class to class are regulated by ministerial decision, after a service of at least two years.

The geologic staff is composed of one director, seventeen engineers of mines, and fourteen geologists not otherwise related to the mining department.

COST.

The expense of the work is not easily estimated. The appropriation for the current year is 80,000 francs ($15,440), but it is not ascertained whether this includes the salaries of the official mining engineers detailed to duty on the survey.

PUBLICATIONS.

The survey under Brochant de Villiers published a general map in six sheets; scale 1–500,000. The two volumes of explanatory text are accompanied by a reduced copy of the map; scale 1–2,000,000.

From 1835 to 1873 there were published detailed maps of 59 departments.

Since 1868 the commission on the detailed geologic map has issued forty-seven sheets on the scale of 1–80,000.

A series of memoirs has been started.

GREAT BRITAIN.

The Government geologic organization is known as the "Geological Survey of the United Kingdom."

ORIGIN AND HISTORY.

Geologic investigation in England was initiated by private individuals and fostered by private associations long before it received government aid. As early as 1801 William Smith, the distinguished pioneer of stratigraphic geology, published a small geologic map of England. In 1815 he published a larger map, covering England and Wales and part of Scotland, and between 1819 and 1824 he produced twenty-one maps of English counties, colored to represent the geologic formations. Similar, though less extensive, work was executed by other persons, and England had already a considerable corps of amateur geologists when, in 1832, the Government bureau was established, under the directorship of H. T. de la Bêche.

The original title of the organization was "The Geological Survey of Great Britain." In 1845 the Geological Survey of Ireland was instituted, and the two corps were jointly entitled the "Geological Survey of the United Kingdom." In 1854 the Geological Survey of Scotland was made a distinct branch; and finally, in 1877, the title "Great Britain" was dropped and the present nomenclature was adopted. The Geological Survey of the United Kingdom includes the Geological Surveys of England and Wales, of Scotland, and of Ireland.

De la Bêche, at first director for Great Britain, afterward became director-general, in which position he was succeeded by Sir R. I. Murchison in 1855, by A. C. Ramsey in 1872, and by A. Geikie in 1881. In 1845 Ramsey was appointed director for Great Britain, and on his promotion in 1872 was succeeded by A. W. Bristow. The first director for Ireland was Capt. H. James, 1845; and his successors were T. Oldham, 1845, J. B. Jukes, 1850, and E. Hull, 1869. The directors for Scotland have been A. Geikie, 1867, and H. H. Howell, 1882.

OFFICIAL RELATIONS.

The Geological Survey was originally instituted as a bureau of the Ordnance Survey, and this relation continued from 1832 to 1845. It was then placed under the Office of Woods and Works; and finally, in 1854, it became a branch of the Department of Science and Art. The Ordnance Survey, however, still furnishes its base maps and executes its map engraving.

In 1837, five years after the founding of the Geological Survey, the Museum of Economic Geology was created, for the purpose of exhibiting the collections of the survey, so as to show the "applications of geology to the useful purposes of life." It was soon discovered that chemic, metallurgic, and mineralogic examinations of the survey collections could be best made in the museum, and its function as a laboratory became quite as important as its educational function. In 1851 it assumed the title of "The Museum of Practical Geology," and was at the same time installed in its present building on Jermyn Street, to which the offices of the Geological Survey were likewise transferred.

The facilities for scientific study afforded by the laboratory, and the demand on the part of the survey for trained assistants, led to giving instruction in certain technic branches; and there was gradually evolved a school of geology and mining engineering, in which the officers and instructors were originally all members either of the Geological Survey or of the Museum. Its organization was rendered definite in 1851, when it was given the name of the "Royal School of Mines." It is now entitled the "Normal School of Science and Royal School of Mines."

In 1859 the Mining Record Office was established. Its primary, or at least its ostensible, object was to collect and preserve information in regard to mines, and especially with regard to the localities of underground chambers liable to be abandoned and forgotten and thus become dangerous to life and property. Its chief function, however, soon became statistic, and in this work it co-operated with the Geological Survey. In 1883 it was transferred to the Home Office, by which change it was practically merged with the corps of Inspectors of Mines, an institution which appears to have no official relation to the Geological Survey.

The Geological Survey, the Museum of Practical Geology, and the Royal School of Mines are closely affiliated. Their publications are for the most part combined, and they occupy the same quarters. The Survey and the Museum are directed by the same individual.

PLANS AND METHODS.

The Geological Survey uses the maps prepared by the Ordnance Survey as a base for its delineation of outcrops. These are partly on a scale of 6 inches to the mile, with great detail of culture, and partly on a scale of 1 inch to the mile. The geologist, with map in hand, visits each individual outcrop afforded by natural or artificial excavation, and plots the limits of the formations with all the precision of which the scale admits, measuring offsets, wherever necessary, from the features represented on the map to points of outcrop. Dips and strikes are recorded on the same sheet.

The geology of the whole country is being published on a scale of 1 inch to the mile, but a scale of 6 inches to the mile is also used for mining regions and for densely-settled districts.

The great work of the British survey is the mapping of formations and the compilation of sections. Its publications have been mainly descriptive, and it has left to private individuals, and to its own members in private capacity, the discussion of the general principles of the science. It has not even combined its large-scale atlas sheets into small-scale general maps, though that work has been performed privately by its officers.

PERSONNEL.

On appointment to an office in the Geological Survey, the incumbent receives a certain salary fixed by law. Each year this is increased by a fixed amount, until a certain maximum is reached; so that within each grade there is promotion by longevity. The criteria of promotion from grade to grade have not been ascertained, but they probably include both seniority and competency. The following table shows the constitution of the scientific staff of 1884, with the maximum and minimum salaries attached to each office:

Scientific staff.	English money.		United States money.	
	Minimum.	Maximum.	Minimum.	Maximum.
	£ s.	£ s.		
1 director-general .... per annum..	....	800 0	....	$3,896 00
3 directors .... do....	400 0	700 0	$1,948 00	3,409 00
3 district surveyors .... do....	400 0	500 0	1,948 00	2,435 00
14 senior geologists .... do....	250 0	350 0	1,217 50	1,704 50
25 assistant geologists .... per diem..	7	12	1 70	2 92
1 paleontologist .... per annum..	300 0	450 0	1,461 00	2,191 50
1 assistant paleontologist .... do....	200 0	300 0	974 00	1,461 00
1 naturalist .... do....	400 0	600 0	1,948 00	2,922 00
1 assistant naturalist .... do....	100 0	175 0	487 00	852 25
4 fossil collectors .... per diem..	3	6	73	1 46
3 general assistants .... do....	3	6	73	1 46

The director-general receives also £300 ($1,461) as director of the Museum of Practical Geology, and various other officials have similar duplication of pay.

COST.

The estimates for 1885 indicate: For the Geological Survey of the United Kingdom, £20,106 ($97,916.22); for the Museum of Practical Geology, £3,919 ($19,085.53); for the Royal School of Mines, £14,852 ($72,329.24). This does not include printing and map engraving. The printing is provided for by a general appropriation for printing. Map engraving is executed for the Geological Survey by the Ordnance Survey, and its cost—that is, the cost of modifying the maps of the Ordnance Survey to express the facts of the Geological Survey—is about £1,500 ($7,305) per annum.

Comparing the total area surveyed from 1873 to 1881 with the total grants of money for the same period, it appears that the work of the survey cost £7 16*s*. ($37.99) per square mile. This includes the expense of field work, office work, and publication. The appropriations for these eight years were remarkably uniform, ranging only from £22,667 (1873-'74) to £24,009 (1879-'80).

PUBLICATIONS.

The principal publications are Maps, Sections, and Memoirs, all of which are placed on sale.

The Maps, on a scale of 1 inch to the mile, are planned to represent England and Wales in 110 sheets, Scotland in 120 sheets, and Ireland in 205 sheets. The size of the earlier-published sheets, known as "old series" or "full sheets," is 24 by 36 inches. The size of the "new series" or "quarter sheets" is 12 by 18 inches. Scotland is exceptional, having sheets of 18 by 24 inches. Of many sheets representing portions of England two editions are published—one exhibiting the solid geology, the other the superficial geology or drift.

Sections are published in sheets to accompany maps, and are of two kinds: horizontal sections, on a scale of 6 inches to one mile, and representing the structure of districts; and vertical sections, on various scales, representing local geologic columns. The number of map sheets and sections published up to 1884 is shown in the following table, taken from Topley's report to the British Association for the Advancement of Science:

Description.	England and Wales.	Ireland.	Scotland.	Total.
1-inch map (1-63,360) (sheets or quarter-sheets in England and Wales):				
Solid. 183	244	180	33	457
Drift edition of solid map 49				
Drift only. 12				
6-inch maps (1-10,560)	216	10	128	354
Horizontal sections	129	30	9	168
Vertical sections	69	1	7	77
Total	658	221	177	1,056

The Memoirs are printed in imperial octavo, and include three series, the first devoted to descriptive and local geology, the second to paleontology, the third to the mining statistics collected by the Mining Record Office. The paleontology is grouped in "decades" and "monographs," and the monographs are accompanied by plates in folio. The statistic series ceased in 1883 with the transfer of the Mining Record Office.

Uniform with the Memoirs, and properly included with them, although differing in name, are a few volumes emanating from the Royal School of Mines, and entitled "The Records of the School of Mines."

The total number of volumes of geologic memoirs (to 1884) is 24; decades, 13; monographs, 4; mineral statistics, 30; explanations of maps, 158.

INDIA.

Geologic investigation is prosecuted by the "Geological Survey of India."

ORIGIN AND HISTORY.

After the temporary employment of various geologists and the occasional institution of preliminary geologic investigations for specific purposes, the geologic survey now existing in India was founded in 1851.

For five years the working force was limited to from three to six officers and assistants, and the results were published unofficially. In 1856 the staff was increased, the labors of the survey were systematized, and the reports were ordered to be published in uniform series.

The subsequent growth of the survey has been due to normal development without essential modification of function.

The superintendent appointed at the origin of the survey in 1851, Dr. Thomas Oldham, remained in charge until 1876, when he was succeeded by the present incumbent, Mr. H. B. Medlicott.

OFFICIAL RELATIONS.

While the laws under which the survey was established and extended are inaccessible, it appears to be an independent government bureau under the immediate control of the Governor-General. Topographic work is not performed; and investigation is generally confined to areas already mapped by the Topographical and Revenue surveys.

A museum has grown up with the progress of the survey; and a division of mining records, having for its special function the collection of records of phenomena brought to light in mining operations, was organized in 1880.

PLANS AND METHODS.

No definite statement of plans or of methods of investigation are given in accessible official documents; but from incidental remarks in the annual reports of the superintendent and from the general character and scope of the various reports already issued, it appears that several ultimate objects are kept in view, among which are the following, viz:

1. The preliminary delineation of the geologic structure of the Indian Empire, upon the basis of the Atlas of India—scale, 4 English miles = 1 inch (1–253,440)—save where the structure is so simple that a smaller scale is admissible, or so complex that a larger scale is required.
2. The ultimate preparation of a geologic map of the empire upon such scale as may be found suitable after the structure has been determined.
3. The full description and illustration of the organic remains of the Indian rocks.
4. The correlation of Indian formations with those of other countries.
5. The discussion of speculations relating to fundamental geologic principles and tending to promote geologic science.

6. The examination of the mineral deposits and the ascertainment of the agricultural capabilities of the empire.

7. The diffusion of information of scientific and economic value among the people of the empire by means of published reports and official correspondence.

PERSONNEL.

The scientific personnel includes a superintendent, two deputy superintendents (one of whom is designated the senior), geologic assistants of three classes, and paleontologists.

In 1877 the personnel and salaries per annum were as follows:

Personnel.	Salary.		Traveling and horse allowance.	
	Rupees.		*Rupees.*	
Superintendent	1, 800	$9, 417 60	200	$1, 046 40
Senior deputy superintendent	1, 400	7, 324 80	140	732 48
Deputy superintendent	1, 100	5, 755 20	130	680 16
First-class assistant	1, 000	5, 232 00	130	680 16
Second-class assistant	700	3, 662 40	130	680 16
Third-class assistant	500	2, 616 00	130	680 16
Paleontologist	500	2, 616 00	130	680 16

The trained specialists are generally imported from Great Britain, while unimportant posts are largely filled by natives. In 188 0, owever, a native geologist was elevated to the lowest rank of the graded staff.

The superintendent is appointed by the Governor-General. The subordinate officers appear to be similarly appointed upon the nomination of the superintendent.

Promotion is generally determined by seniority and by proficiency. It is specifically pointed out (Records, V, 1872, 1) that "every new assistant is comparatively worthless for one whole working season, until he has become acquainted with what has been done, and can thus take his place with the others in extending this knowledge."

The superintendent exercises general oversight of publication as well as investigation, but it is the professed policy to distribute responsibility by publishing all reports under the names of their authors, and holding the authors answerable for statements and opinions.

COST.

The expenses of the survey appear to be met by special appropriations from year to year, but no information as to amounts has been obtained.

PUBLICATIONS.

The publications of the survey belong to several series, chiefly the octavo "Memoirs", the octavo "Records", and the folio "Paleontologia Indica."

From its organization in 1851 to its extension in 1856, the reports of the survey were published "in various journals, and in different forms." In the latter year separate publication of the annual reports of the superintendent was instituted, and continued until 1868, during which period twelve of the reports appeared in octavo pamphlets.

Publication of the Memoirs began in 1859 under the provision of 1856 for "publication of reports in a uniform series." These memoirs contain independent treatises upon specific areas, formations, taxonomic or speculative questions, and other clearly defined subjects, prepared by different members of the staff, and issued from time to time as the material accumulates. Twenty-two volumes of the series have been issued.

The Paleontologia Indica, or figures and descriptions of the organic remains of the rocks of India, consist of elaborate monographs of the fossils of particular localities or formations. They are splendidly illustrated by expensive plates of fossils. Publication of the series was commenced in 1863. About fifty of the monographs have already appeared.

The Records comprise the annual reports of the superintendent upon the work of the survey and the condition of the museum, and minor treatises by the different officers of the survey upon special subjects, particularly those of immediate economic or scientific interest. Their issue began in 1868, since which time seventeen volumes have been published.

About 1870 the publication of geologic maps on the basis of the Atlas of India (4 miles = 1 inch) was undertaken, and in 1873 a number of maps on a scale of 1 mile = 1 inch were issued. The employment of so large a scale was, however, found to be inexpedient, save in areas of exceptionally complex structure. Separate publication of maps ceased in 1874. Since that date, as well as previous to 1870, the memoirs and records have been illustrated by geologic maps of different scales, constructed upon bases prepared by the Topographical and Revenue surveys. They are printed in the Surveyor-General's lithographic office.

In addition to the foregoing, a Manual of the Geology of India, in three volumes with a portfolio map, has been brought out.

The various publications are sparingly exchanged among other scientific organizations, and the remainder are sold.

GERMANY.

The geologic surveys in the Empire of Germany are not wholly under the direction of the Imperial Government. Several of the states have geologic surveys of their own; among them, those of Prussia, Saxony, Alsace-Lorraine, and Bavaria are most important.

PRUSSIA.

The beginning from which the present Royal Geologic Institute of the Prussian states has gradually developed dates back to 1862. At first the investigations were carried on under the royal superintendence of mines, constituting a division of the department under the Minister of Commerce, Industry, and Public Works. Some of the professors of the Mining Academy were connected with the geologic investigations, and as the work progressed the survey became more and more intimately connected with the Mining Academy. The researches in the various districts were not correlated, and as they advanced it became evident that co-operation was desirable.

For the purpose of developing a plan of concerted action, a conference of the geologists of northern Germany was called in 1867 to meet at the Mining Academy of Berlin. At this meeting one of the counselors of mines, in the name of the Minister of Commerce, Industry, and Public Works, presented a plan for the apportionment of the work among those who were actively engaged in geologic investigations. The scheme was adopted, but before long it became apparent that it was necessary to have not only co-operation among individuals not officially related, but also to have co-ordination and complete organization. With this object in view, Counselor of Mines Hauchecorne prepared an extensive scheme for the organization of the Royal Geologic Institute and Mining Academy (Königliche Geologische Landesanstalt und Bergacademie) of Prussia, at Berlin. His recommendations were adopted, and went into effect in 1873. The survey was modeled chiefly after those of England and Austria.

OFFICIAL RELATIONS.

The survey is connected with the department of the Minister of Commerce, Industry, and Public Works, who appoints subordinates on the survey upon the nomination of the directors. The latter are appointed by imperial authority. The work of the Institute and Mining Academy is entirely of a geologic character. The topographic maps which it uses had previously been prepared by another department of the government.

PLANS AND METHODS.

The plans and methods of the Institute and Mining Academy are defined in the organic law, and may be briefly summarized as follows:

I. The object of the Royal Geologic Institute is to carry out the geologic examination of the Prussian dominions, and elaborate the results, so as to make them accessible and useful for science and for the economic interests of the country.

II. Accordingly, the Geologic Institute is to accomplish the following work:

(1) The execution and publication of a special geologic map of the whole Prussian domain, based on the original drafts of the general staff, on the scale of 1-25,000. This special map is to contain a complete representation of the geologic conditions, the quality of the soil, and the occurrence of useful rocks and minerals, and is to be accompanied by explanatory text.

(2) The execution of a geologic review map, based on the map of the general staff, on the scale of 1-100,000, in accordance with the progress of the special map.

(3) The monographic description of the geology of separate districts or mineral groups.

(4) The publication of treatises relating to or connected with geology and paleontology to correspond with the maps.

(5) The collection and preservation of all reports referring to these maps and to other works.

These, together with the maps and profiles and other representations, are to be united into a National Geologic Museum, to which the technologic collections of the Museum for Mining and Smelting are to be subordinated. These united collections are expected to afford as perfect a sketch as possible of the geologic composition of the country, the quality of the mineral wealth, and the industries depending on the mineral wealth.

III. The heads of the Geologic Institute are to be two directors, named by the King, one of whom is to be director of the Royal Academy of

Mines. Under their direction and with their co-operation the works of the Geologic Institute are to be carried out by Government geologists and by a number of collaborators. The duties of the Government geologists and of their collaborators are to be regulated by special rules.

IV. The common duties of the two directors of the Geologic Institute are as follows: (1) The determination of the annual plan of operations; (2) the supervision of its systematic execution; (3) the preparation for the conferences of the geologic collaborators and the execution of the measures decided on in these conferences; (4) the revision of the annual work of the collaborators; (5) the direction of all the publications of the institute; (6) the direction of the collections for the National Geologic Museum; (7) the return of an annual report on the progress of the work.

V. Connected with the National Geologic Institute is the Royal Academy of Mines. Its plan of teaching embraces the following subjects: (1) Mining; (2) general knowledge of smelting works; (3) iron furnaces; (4) salt mining; (5) general assaying; (6) blow-pipe assaying; (7) iron assaying; (8) drawing of structures; (9) metallurgic technology; (10) chemic technology; (11) geodesy, surveying, and mathematic geography; (12) practical exercises in geodesy and surveying, and in plotting; (13) general knowledge of machinery; (14) machines for mines and furnaces; (15) practice in construction; (16) drawing; (17) building; (18) plane and spherical trigonometry, stereometry, and analytic geometry; (19) differential and integral calculus; (20) descriptive geometry; (21) mechanics; (22) mineralogy; (23) practice in mineralogy; (24) petrography; (25) practice in petrography; (26) geognosy; (27) paleontology; (28) general geology; (29) exercises in chemic laboratory; (30) recitation in analytic chemistry; (31) mining jurisprudence.

The course of study is designed to extend over three years, and only those persons are admitted who have had special preparation and intend to fit themselves for the public service.

The director of the academy is charged with its supervision, being assisted by a board consisting of five members appointed by the Minister of Commerce, Industry, and Public Works. This board is to co-operate with the director in fixing the organization of the academy and plan of studies.

From the above summary it will be seen that Prussia has formulated in the organic law of its geologic survey a plan for obtaining the assistance of a body of collaborators composed of the professors of geology in educational institutions and other private persons who cultivate the science, the purpose being to enlist in the survey the best talent of the country. In addition to this the official geologists have careful and elaborate training in the Mining Academy.

PERSONNEL.

In the year 1880 the personnel of the Royal Geologic Institute and Mining Academy included one first director, one director, eight geologists, four assistants, seventeen associates, nine instructors, seven chemists, and seven administrative officers.

PUBLICATIONS.

The publications of the survey are of three kinds: (1) Maps in sheets, with brief explanatory notes; (2) Memoirs (Abhandlungen); and (3) Annual Reports (Jahrbücher).

A number of maps are usually published together, and, unless required by circumstances to be otherwise, are on the scale of 1–25,000. They are distributed to schools and public institutions. They can be purchased at very low rates, about two marks (50 cents) for a colored sheet representing an area of two and a half square miles (German= 38 miles English).

The Memoirs contain the longer articles, with illustrations, maps, &c., and the shorter contributions are found in the Annual Reports. During the year 1880 1,437 map sheets and 61 memoirs were sold.

BAVARIA.

ORIGIN AND HISTORY.

The geologic survey of the Kingdom of Bavaria (Anstalt der Geognostischen Untersuchung des Königreichs Bayern) originated in 1850, at the instance of the Counselor of State. To the commission formed for its control in the Department of Public Works three members of the Academy of Science were added. C. W. von Gümbel was appointed director in 1851, and occupies that position at the present time.

OFFICIAL RELATIONS.

In 1869 the Superior Council of Mining was established, and the geologic survey was made a section in that department.

PLANS AND METHODS.

The field operations of the survey began in 1851 by using the cadastral maps on a scale of 1–5,000. The scale of publication is usually 1–100,000, but in special cases it is 1–50,000.

Professor von Gümbel is allowed a number of assistants, who are usually prepared for their work in the School of Mines. They are employed only temporarily, and afterward pass into other government offices. In this way it is intended to form a practical school in which young workers may be trained in geologic investigations. In 1869, when the survey was reorganized, a chemic laboratory for its use was instituted.

COST.

An annual appropriation of 11,000 florins (about $4,400) was allowed the survey at the time of its establishment. Whether any changes have been made in the amount appropriated since 1869 is unknown. Assistant investigators employed temporarily are paid from 2 to 3.30 florins ($0.80–1.32) daily for office work, with increase during field work of from 2.30 to 3 florins ($1.02–1.20) in addition to traveling expenses.

PUBLICATIONS.

In 1863 the first volume of five maps appeared, and in 1868 the second volume; the third is yet in course of preparation.

The explanation of separate sheets is not published, but the maps are grouped for the purposes of explanation, as follows:

1. "Geognostische Beschreibung des Bayerischen Alpengebirgs und seines Vorlendes," 5 maps. Cost, 96 marks ($24).

2. "Geog. Besch. des Ostbayerischen Grensgebirgs," 5 maps, 108 marks ($27).

3. "Geog. Besch. des Fechtelgebirgs und Frankenwaldes," 2 maps. 70 marks ($17.50).

There is no official general map; but the director has published the following, without text: "Geog. Uebersichts-karte des Königreichs Bayern," München, 1858. 1–500,000. Price, 17.20 marks ($4.30).

SAXONY.

OFFICIAL RELATIONS.

The Royal Geologic Investigation of Saxony (Königliche Geologische Landesuntersuchung von Sachsen) dates from 1872. It is in the department of the Minister of Finance. The director from the beginning has been Hermann Credner, who is also professor in the university at Leipsic. The topographic maps used are those already published by another department of the government.

PLANS AND METHODS.

The kingdom is divided into small sections, which are taken up singly by the assistant geologists, under the immediate supervision of the director. Each section is investigated by one assistant (rarely two), whose name appears upon the map, to indicate who is responsible for the work.

PERSONNEL.

The personnel of the survey consists of one director and eight assistant geologists.

PUBLICATIONS.

The maps are published on a scale of 1–25,000, by a private firm in Leipsic, and are for sale to the public at a very low price—two marks (50 cents) for each colored sheet and one mark (25 cents) for the accompanying explanatory text. No memoirs, aside from the explanatory texts (Erlauterungen) which accompany the special maps, have been published.

ALSACE-LORRAINE.

A commission for the geologic survey of Alsace-Lorraine has been formed at Strasburg. The director is E. Cohen. It has published numerous geologic maps in sheets on the scale of 1–25,000. The maps are accompanied by text, and may be purchased by the public at a very low rate. It also publishes memoirs (Abhandlungen).

OTHER GERMAN STATES.

Geologic surveys of some of the other German states have been made on a scale of 1–50,000, not all directly by the government. One has been made of Baden by Zittel and Sandberger. A special map of Hesse has been prepared by the Mittelrheinischer Geologischer Verein of Darmstadt.

A map of Upper Silesia has also been prepared on a scale of 1–10,000.

AUSTRO-HUNGARY.

The Royal-Imperial Geologic Institute of Austria (Königliche Kaiserliche Geologischen Reichsanstalt) is designed to cover the whole domain, but more or less independent surveys have been organized in Hungary and Bohemia.

AUSTRIA.

ORIGIN AND HISTORY.

Previous to the year 1850 all the geologic work done within the Empire of Austria was either at private expense or under the auspices of the "Geognostisch-Montanischer Verein," which received an annual allowance of 10,000 florins ($4,000) from the government.

In the latter part of 1849 the Minister of Agriculture and Mining addressed a communication to the Emperor, setting forth the importance of organizing an imperial institute for the geologic investigation of the Austrian Empire, and proposing a scheme by which the result might be accomplished. Attention was called to the fact that England, France, Saxony, Prussia, Russia, and some of the United States of America had already organized geologic surveys.

The Emperor approved the plan suggested by his minister, and thus created the Imperial Geologic Institute of the Austrian Empire in 1849.

OFFICIAL RELATIONS.

The director of the Geologic Institute is appointed by the Emperor, but the Minister of Agriculture and Mining, to whose department the survey belongs, appoints, on the nomination of the director, the geologists and other officers of the institution. The Geologic Institute is furnished with topographic maps by the Imperial Military Geographic Institute.

PLANS AND METHODS.

The objects to be accomplished by the survey were briefly set forth by the Minister of Agriculture and Mining as follows: The geologic exploration and investigation of the entire empire; the determination and systematic arrangement of all the minerals and fossils in a museum; the chemic examination of all the earths, rocks, ores, furnace products, and other specimens from various parts of the empire; the revision of the geologic maps already published, and the preparation of new special and general maps upon the scale of the general staff maps; the preparation of maps, statistic tables, and memoirs, as contributions to general knowledge.

To accomplish the objects enumerated the following means were suggested: (1) a director for the institution, with the title and rank of a section counselor; (2) permanent geologists, with the title and rank of counselor of mines, to conduct the selection and systematic arrangement of the material already collected, and during the summer months to make a geologic investigation of some district; (3) temporary geologists according to the needs of the director (young men holding commissions in other branches of the public service may be used as occasion requires); (4) a museum in which to properly study and store the material collected, under the care of an assistant; (5) an editor to collect, register, systematically arrange, and prepare for publication material already on hand or that may appear as the work advances; (6) servants for the editor and assistants in the museum.

When the Geologic Institute was organized it was designed to encourage private investigation by offering means of publication. One of its essential features is the fortnightly meetings it holds at Vienna. At these meetings all persons interested in the natural sciences are invited to take part in the discussions. The members of the Geologic Institute read papers upon the subjects of their investigation, and any one not officially connected with the survey, having a contribution worthy of attention, can have an opportunity of making it public. Reports of the proceedings at these meetings are published in the Vienna News, so as to spread as widely as possible among the people accounts of its deliberations. To furnish a yet wider and more special distribution, the proceedings of the Geologic Institute are published in annual volumes (Verhandlungen).

Some time after the organization of the survey the Austrian territory was divided into sections, and the working force was so distributed as to carry on investigations in all the sections.

PERSONNEL.

In 1862 the personnel of the survey consisted of one director, one first geologist, one editor, one assistant, five geologists, one chemist, one librarian, one draftsman, and seven laborers, including in all twenty persons. Nearly twenty years later (1881) there were twenty-six persons connected with the survey, as follows: one director, one vice-director, three chief geologists, one chemist, two geologists, two adjuncts, one assistant, one practitioner, four volunteers, one draftsman, two administrative officers, and six laborers.

COST.

In 1849, when the Geologic Institute was founded by the Emperor, he allowed it an annual appropriation of 31,000 florins ($12,338). In 1871 the expenses of the survey were 43,355 florins ($17,255.29), distributed as follows:

	Austrian money.	United States money.
	Florins.	
Personnel	19, 335	$7, 695 33
Office expenses, steam, &c	5, 000	1, 990 00
Traveling expenses	5, 750	2, 288 50
Museum expenses	4, 100	1, 631 80
Laboratory expenses	600	238 80
Rent	8, 270	3, 291 46
Maintenance, &c	300	119 40

The chief portion of the personnel of the survey have, besides their salaries, an allowance for quarters.

PUBLICATIONS.

The publications of the survey are of three kinds, Maps, Annual Reports (Jahrbücher), and Proceedings (Verhandlungen).

The complete map of the country will be in 715 sheets, of which 270 have already been published. The prices vary from 1 to 8 florins. The field work is usually done on a scale of 1–25,000 and published on a scale of 1–75,000.

From the beginning of the survey in 1850 until 1866 the reports upon the proceedings of the Institute and its discussions, as well as the more important papers of the survey, were published in the Annual Report, but since that time the proceedings and discussions have been published in annual volumes entitled "Verhandlungen," while the more important papers, with illustrations, maps, &c., continue to appear in the Annual Report. The contributions considered within the range of the Annual Report, according to its prospectus, are (1) reports upon the explorations of the geologists, with the necessary illustrations, maps, sections, &c., as also communications in the form of preliminary reports upon regions not directly examined, to prepare the way for later investigations; (2) communications upon every branch of natural science related to geology, as geography, meteorology, physics, chemistry, mineralogy, and paleontology; (3) practical appliances in mining and metallurgy; (4) agricultural lands, building and other useful materials; (5) the historic relations of the survey, its personnel, plans of research, specimens received and distributed; (6) statistic tables of the productive industries.

The selling price of the first Annual Report (1850) was 5 florins ($2).

HUNGARY.

In 1868 the Hungarian Minister of Commerce, Industry, and Agriculture formed a geologic section in his department to co-operate with the members of the Imperial Geologic Institute of Austria who had been sent to investigate portions of the Hungarian territory.

In 1869 the section was enlarged to the Royal Geologic Institute of Hungary (Magyar Királyi Földtani Intézet), by the same minister. The King appointed the director of the survey, and the Minister of Commerce, Industry, and Agriculture, under whose department the survey was organized, appointed the chief geologists, assistant geologists, and other subordinates. After 1869 the geologic survey of the Hungarian territory was carried on chiefly by its own government, although some work continued to be done by the members of the Austrian survey.

PUBLICATIONS.

The Royal Geologic Institute publishes small annual reports of progress, with maps and illustrations. Some of the most important contributions have been published in both the Hungarian and German languages.

BOHEMIA.

A natural history survey of Bohemia has been organized, and has published important contributions to science.

SPAIN.

The official geologic survey is styled the Commission of the Geologic Map of Spain (La Comisión del Mapa Geológico de España).

ORIGIN AND HISTORY.

In order to clearly set forth the conditions and functions of the commission it is necessary to briefly review the early Spanish organizations of like aims.

More or less comprehensive researches were instituted under governmental authority in the years 1829, 1831, 1832, and 1835. Measured by results, that of 1832, conducted by Don Guillermo Schulz, and confined to the four Galician provinces, was of greatest value. Within two years from its initiation this survey was completed, and a geologic map of Galicia (Mapa petrografico del Galicia, 1834) published. Interest in geologic investigation then waned and did not again revive for twenty-five years.

By royal decree of July 11, 1849, a commission was created and empowered: (1) to prepare a geologic map of the province of Madrid, and (2) to collect data for a general geologic map of the kingdom. It comprised four sections, viz: (1) geography and meteorology; (2) geology and paleontology; (3) botany; and (4) zoölogy. By reason of the diverse functions of this commission and the necessity for expensive topographic work, purely geologic work suffered continual retardation. In spite of these adverse circumstances it was energetically pushed forward by the leader of the commission, Don Casiano de Prado. In the course of seven years preliminary maps of seven provinces and a geologic description of one province were published.

In 1854 three sub-commissions were formed to study different coal-bearing regions, but only one was so far successful as to publish reports.

For several years the commission was embarrassed by the inadequacy of the means at its disposal; but in 1860 its funds and functions were increased, and during the succeeding three years much valuable work was accomplished.

About 1863 the geologic work of the kingdom became differentiated and fell into the hands of different governmental institutions. On September 30, 1863, there was issued a royal order establishing a commission of mining engineers to exploit the coal fields of the Asturias under the superintendence of the Department of Agriculture, Industry, and Commerce. The operations of this commission were mainly geographic up to the time of its dissolution in 1870. At the same time geologic researches were prosecuted by the Bureau of Statistics; and in 1864, perhaps the most elaborate report ever issued in Spain, Prado's Physical and Geologic Description of the Province of Madrid, was published by the bureau. Shortly after the appearance of this important treatise, a permanent commission of industrial geology, with Don Casiano de Prado as its chief, was organized in the Bureau of Statistics, and with it three subordinate commissions were established and charged with geologic investigation in different parts of the kingdom. These commissions appear to have accomplished little of permanent value. Geologic work was prosecuted under the auspices of the Bureau of Statistics up to 1868, at which date it was relieved of that portion of its duties. Thus, toward the close of the decade preceding the origin of the present organization, there were in existence in Spain five geologic commissions of different ranks, under two government departments; and none of these were making satisfactory progress. Notwithstanding the multiplicity of surveys designed to secure information relating to her rocks, little was definitely known concerning the general structure of Spain, and fully one-half of her provinces were unknown geologically.

Just before the commencement of the last decade the reaction following the abnormal differentiation of geologic work began to be felt throughout Spain, and a unification was effected in 1870, when the existing commission was created (April 28). This commission soon absorbed the older one engaged upon the coal fields of the Asturias.

In 1873 the commission was transferred to the Bureau of Mines, and its status was so changed as to secure the co-operation of the engineers employed by that bureau. Since its transfer the commission has progressed steadily, under the able directorship of Don Manuel Fernandez de Castro, toward the accomplishment of the objects of its founders. Its investigations have extended over most of the country. Maps of twenty-seven of the forty-eight provinces, and many volumes of text, have been published. It is estimated that the survey will be completed and a map of Spain, in sixteen sheets, on a scale of 1–400,000, published within four or five years.

OFFICIAL RELATIONS.

The commission is a special section of the civilian Board of Mines of the Department of Public Works, Agriculture, Industry, and Commerce.

The professors of geology, paleontology, mineralogy, analytic chemistry, and assaying in the Special School of Mines constitute *ex officio* members of the commission.

PLANS AND METHODS.

The general function of the commission, as formulated in the decree establishing it, is to make maps or sketches of the unsurveyed provinces, and, by combining their own and all previous observations, to prepare a geologic map and description of the kingdom. In this work the commission has the co-operation of the entire staff of the Bureau of Mines, whose geologic results are placed at its disposal.

Since the geographic surveys of Spain are incomplete, the preparation of geologic maps involves the prosecution of geographic surveys and the construction of base-maps. These duties were performed by the geologic commission during the earlier years of its existence; but since the commencement of the topographic work, in 1875, the sheets issued by the official topographic survey have been employed in the geologic work.

Especial care has been exercised from the outset to impress upon the investigations a practical character, and to render the results immediately subservient to purposes of agriculture, mining and related interests, engineering and constructive works, &c.

It is especially provided that maps and memoirs shall be published under the names of their authors, who are thus made individually responsible for their work and receive due credit for the scientific discoveries they make.

PERSONNEL.

In 1883 the personnel comprised a director, a secretary, six mining engineers, and seven or eight assistants, together with four professors of geologic science in the School of Mines.

PUBLICATIONS.

Previous to 1873 several treatises descriptive of different provinces were issued. One of these was accompanied by a topographic triangulation and survey of the Province of Cuenca on a scale of 1–10,000.

The publication of systematic reports was commenced in 1873 under a special order of the department. Three series of publications are issued, viz, (1) Memoirs (Memorias), (2) a Bulletin (Boletin), and (3) sheets of the general map of the kingdom. The Memoirs and Bulletins are modeled after the publications of the geologic societies of London and Paris.

The Memoirs are quarto monographs, generally relating to single provinces, and accompanied by maps on a scale of 1–400,000; but they are sometimes devoted to other clearly-defined subjects. In addition to the uniform maps they are sometimes illustrated by maps on special scales, sections, views, and plates of fossils. Ten volumes, of from 200 to 400 pages, have been issued.

The Bulletin comprehends minor treatises on special subjects, translations of foreign memoirs on Spanish geology, reports of progress in various districts, and miscellaneous material, besides reduced copies of the final maps of those provinces whose surveys are completed from time to time, and explanations of these maps. They are also illustrated by maps on special scales. The issue of the Bulletins began in 1876, since which date twelve octavo volumes, of from 300 to 500 pages each, have appeared.

The publication of the final map is not yet commenced. The first sheet will probably be published during the present year.

A limited number of copies of the publications of the commission are subscribed for by the department, and these are distributed gratuitously or by exchange among libraries and scientific institutions. The remainder are sold by annual subscription and in open market, at prices probably yielding profit. The subscription price for Memoirs and Bulletins together is 30 pesetas ($5.80) per year.

PORTUGAL.

The official geologic exploration is conducted by the Geologic Commission of Portugal (Commissao Geologica de Portugal) or Geologic Section (Secçao dos Travalhos Geologicos).

ORIGIN AND HISTORY.

By decree of December 31, 1852, the Portuguese government authorized the creation of a special commission having for its function the prosecution of surveys, the collection of material, and other duties pertaining to the construction of a geologic map of the kingdom. The organization of the commission contemplated in this decree was not effected until 1857, when it was permanently established and its relations and duties defined. Whether by reason of apathetic administration or of inadequate support, its progress has been dilatory. A preliminary edition of the map of the kingdom, on a scale of 1–500,000, was published in 1876.

Joaquim Filippe Nery Delgado is the present chief of the Geologic Section.

OFFICIAL RELATIONS.

The Geologic Section was instituted as a subordinate bureau of the geodetic commission organized in 1833, and charged with the geodetic, topographic, hydrographic, and geologic work of the kingdom. It is specifically provided that the Geologic Section shall be "independent in the performance of all scientific work," and that "it shall correspond accurately with the national scientific bodies of other countries."

PLANS AND METHODS.

By the royal decree effecting its organization the duties of the survey were defined as follows: (1) to establish a general plan of operations;

(2) to have the kingdom traversed by specialists whose observations and conclusions shall be recorded and classified; (3) to correlate facts of geologic structure collected by the special investigators, and to represent the geology of the entire kingdom on a map of suitable scale.

PERSONNEL.

The corps comprises two directors-general (one of whom is designated the chief), two subordinate members, and four assistants.

PUBLICATIONS.

A preliminary general geologic map was issued in 1876; scale 1–500,000.

There have been published fifteen quarto monographs treating of special investigations on geology, paleontology, and archæology, and an octavo treatise on agriculture and forestry. The monographs are illustrated by lithographic plates and by geologic and other maps on special scales.

The several publications are distributed gratuitously.

ITALY.

The official organization is styled the Royal Italian Geologic Committee (Reale Comitato Geologico d'Italia).

ORIGIN AND HISTORY.

After various futile attempts to initiate geologic researches without making adequate provision for the cost necessarily attaching, the Italian Government established the existing Comitato, by a royal decree, on December 15, 1867. The decree recites that "the geologic section of the Royal Corps of Mining Engineers is hereafter established as a Comitato Geologico," and goes on to specify the duties of the Comitato, formulate detailed plans for the administration of its affairs and the prosecution of the work of the survey, and make provision for its maintenance. A survey was at once instituted by the Comitato and successfully carried on for six years. By decree of June 15, 1873, the constitution of the Comitato was modified, and its office transferred from Florence to Rome. Again, in 1879 the Comitato was reorganized, though without material modification of function, by decree of January 23. Since that date the survey has been greatly extended and established on a permanent basis; and many important maps and treatises have been issued.

OFFICIAL RELATIONS.

The Comitato is in the department of Agriculture, Industry, and Commerce. It was originally made up of five members; but the membership has been increased from time to time until it now reaches nine or ten, including two *ex-officio* members, viz, the Chief Inspector of Mines and the Director of the Military Topographic Institute.

This organization appears to form a semi-official geologic institute, and holds regular meetings in which geologists not connected with the government sometimes participate. During the session the plans of the survey are formulated, its affairs are regulated, its results are discussed, and the maps and memoirs presented for publication are examined and the expediency of publication decided upon. Formal papers on geologic subjects appear also to be presented and discussed.

The members of the Comitato serve gratuitously; but those non-resident in Rome are reimbused for traveling expenses incident to attendance of sessions.

The actual work of the survey is performed by a section of the Royal Corps of Mining Engineers, which constitutes a geologic staff (*Ufficio Geologico*). The present director of the staff, Dr. Giuseppe Meneghini, is professor of geology in the University of Pisa; and other members of the staff appear to be similarly connected with different Italian universities.

A cabinet, library, laboratory, and regularly appointed office exist at the headquarters of the survey—at present the Royal School of Engineering.

PLANS AND METHODS.

The principal function of the survey is the preparation and publication of the geologic map of Italy, upon the basis of the map issued by the Topographic Military Institute, the scale of which is 1–50,000. The preliminary maps are, however, of various scales. The preparation and publication of suitably illustrated monographs was also contemplated at the outset.

Methods of work are fixed in detail, from time to time, by the Comitato Geologico. It is provided in the law establishing the survey that all publications shall appear under the names of their authors, and also that particular formations shall be assigned to geologists specially familiar with them.

PERSONNEL.

The staff comprises a "superior personnel" and a "subaltern personnel." In 1883 the officers and their salaries were as shown in the accompanying table:

Staff.	Salaries.		Aggregates.	
	Italian money.	United States money.	Italian money.	United States money.
	Lire.		*Lire.*	
Superior:	9,000	$1,800	9,000	$1,800
One director ....each..				
Four geologists of first class ....do....	7,000	1,400	28,000	5,600
Two geologists of second class ....do....	4,000	800	8,000	1,600
Two geologists of third class ....do....	3,000	600	6,000	1,200
Four assistants ....do....	2,000	400	8,000	1,600
One secretary ....do....	3,000	600	3,000	600
One petrographer ....do....	7,000	1,400	7,000	1,400
One paleontologist ....do....	7,000	1,400	7,000	1,400
One chemical assistant ....do....	2,600	520	2,600	520
Subaltern:				
Four designers ....do....	2,000	400	8,000	1,600
One copying clerk ....do....	1,800	360	1,800	360
One watchman ....do....	1,500	300	1,500	300
Two servants ....do....	1,200	240	2,400	480
Total	59,100	11,820	92,300	18,460

Candidates for appointment to the lowest rank in the "superior personnel" must be "engineer or bachelor graduates of physical and natural science," graduates of universities, technologic schools, and similar institutions of the kingdom, or, if imported from abroad, they must have either sustained geologic theses in one of the special schools of the kingdom or published important contributions to geologic science.

Appointments are for two years. They are made by the Minister of Agriculture, Industry, and Commerce, upon nomination of the Comitato.

Promotion depends upon proficiency as indicated by the acquisition of honorary titles and the successful performance of duties.

COST.

The annual or aggregate cost of the survey cannot be ascertained, since the most important expenditure, salary, is mainly paid out of the funds of the corps of mining engineers. The expenditures of the survey during 1882 and 1883, exclusive of salaries, are shown in the accompanying table:

	1882.		1883.	
	Italian money.	United States money.	Italian money.	United States money.
	Lire.		*Lire.*	
Field expenses	20,705	$4,141	27,708	$5,542
Office expenses	6,440	1,288	6,523	1,305
Traveling expenses outside the kingdom	2,999	600	6,486	1,297
Publication	8,383	1,677	11,269	2,254
Remuneration of special draftsmen, &c	5,880	1,176	8,885	1,777
Contributions to general map of Europe	4,291	858	2,111	422
Geodynamic service	3,000	600	7,115	1,423
Transfer of office property	6,129	1,226	10,062	2,012
Total	57,827	11,566	80,159	16,032

The aggregate cost of the survey for the eighteen years preceding 1882, exclusive of salaries, was about 4,000,000 lire ($800,000). If the ratio between salary and other expenditures obtaining in 1882 and 1883 holds throughout, the total aggregate cost has been nearly $3,000,000.

PUBLICATIONS.

The publications belong to three series, viz, octavo Bulletins, quarto Memoirs, and geologic Maps.

The Bulletins are issued in bimonthly parts, and form a volume of about 600 pages annually. Their publication began in 1870. Fifteen volumes have appeared.

The Memoirs comprise explanations accompanying the different sheets of the map, and special monographs on subjects suggested by the investigations of the survey. They are published in numbers, designed for combination in volumes. Since the appearance of the first number, in 1871, three complete volumes have been issued.

The Maps are of various scales and dimensions. A preliminary map of the kingdom on a scale of 1-1,111,111 has been published. Six maps of different provinces, three on a scale of 1-100,000, one on a scale of 1-250,000, and two on a scale of 1-400,000 have also appeared.

The various publications are sparingly exchanged. The remainder of the edition is sold at about the cost of printing and paper. The proceeds revert to the survey.

SWEDEN.

There is in Sweden an official geologic survey (Sveriges Geologiska Undersökning).

ORIGIN AND HISTORY.

The institution of official geologic researches in Sweden was first proposed in 1855 by the Agricultural Society of Upsala and the Swedish Agricultural Congress. The proposition was referred by the King to the Agricultural Academy and the Academy of Sciences, and upon their favorable recommendation a survey was organized by a royal decree bearing date of April 27, 1858, and placed under the direction of Dr. Alexander Erdmann. Sixty thousand crowns ($16,080) were appropriated for its maintenance for three years. When first organized the survey appears to have been an unimportant bureau of semi-official character, like those now existing in Norway. It has, however, progressively increased in importance, until to-day it ranks among the foremost of European geologic surveys. A geologic and paleontologic museum, a chemic laboratory, an extensive library, and other appointments essential to effective scientific work have been built up within it, and occupy a portion of the government building assigned to the survey for office purposes.

In 1869 Dr. Erdmann was succeeded in the directorship by Dr. Alfred Elis Törneböhm, of the Polytechnic Institute. The present director, Prof. Otto Torell, assumed control in 1871.

During the first eighteen years of the existence of the survey (1858 to 1876) the area surveyed was 415 Swedish miles (18,300 English square miles) on the 1–50,000 scale, and 96 Swedish miles (4,200 English square miles) on the 1–100,000 scale—apparently reduced to 1–200,000 in publication. The results of these surveys were recorded on seventy-nine sheets of the staff and economic maps.

OFFICIAL RELATIONS.

The survey is in the Interior Department. Several members of the staff belong to different Swedish educational institutions. Between these institutions and the survey there is co-operation, but no official relation.

PLANS AND METHODS.

When the survey was organized it was enacted that it should be executed according to a general plan having principally in view the geologic structure of the country, with due regard to the scientific, agricultural, and manufacturing interests, and that the results should be exhibited by means of detailed maps and descriptions.

The geologic discoveries are recorded in part on the maps of the staff survey, on scales of 1–50,000 and 1–100,000, and in part on the statistic and agricultural maps of the kingdom, on a scale of 1–50,000. These maps are designed for ultimate combination in a general geologic map of Sweden.

The staff and economic maps do not exhibit altitudes. Hypsometric work is acccordingly performed by the geologic survey. Certain maps, designed to promote agriculture, represent the character of the soil in great detail; others indicate the superficial deposits in a general way, but accurately represent all exposures of the sub-terrane.

PERSONNEL.

The permanent staff consists of a director and eleven geologists.

Temporary assistants are employed during the summer, generally from May 15 to October 15.

The salaries are not published. A portion of the staff appear to be salaried in part by educational institutions with which they have connection.

COST.

The annual appropriations have progressively increased since the organization of the survey. For the years 1876 and 1878 the appropriations were, respectively, 71,200 kroner and 83,000 kroner ($19,000 and $22,250).

PUBLICATIONS.

The publications of the survey comprise four series: (1) The 1–50,000 map, with accompanying descriptions (series Aa); (2) the 1–200,000 map (series Ab); (3) general maps (series Ba); (4) special maps, with descriptions (series Bb); and (5) Transactions and Notes (Athandlinger och Uppsatser), in octavo and quarto (series C).

1. Publication of the 1–50,000 map began in 1862. The sheets are numbered in order of publication, are 22¾ by 31¼ inches in size, and each is accompanied by an explanation (beskrifningar) in text. Eighty-six have been issued. Text and sheets are sold at 2 kroner (54 cents) for full sheets, and 1.5 kroner for coast sheets.

2. Ten sheets of the 1–200,000 map, with accompanying explanations, have been published. The sheets are 14 by 18½ inches. They are sold at 1.5 kroner (40 cents).

3. The general maps relate to general, theoretic, or technic subjects. They are of different scales, dimensions, and prices. Three have been published.

4. The special maps relate to mining or agriculture, or represent areas of exceptionally complex structure. They are of unlike scales and dimensions. Only two have thus far appeared. They are sold for 2 kroner (54 cents).

5. The Transactions and Notes comprehend memoirs on stratigraphic, petrographic, paleontologic, economic, and theoretic subjects, illustrated by maps of special scales, plates of fossils, sections, sketches, &c., which are sometimes incorporated in accompanying atlases. They are generally printed in Swedish, but occasionally in English, German, or French. Fifty-four of these memoirs have been issued. They are sold at prices probably not exceeding cost.

NORWAY.

ORIGIN AND HISTORY.

The survey was authorized in 1858, at the instance of T. H. Kjerulf, professor of geology in the University of Christiania, and T. Dahl, chief engineer of mines. In 1866 it was divided, Prof. Kjerulf retaining the main organization, to which was given the title "Geologic Survey of Norway" (Norges Geologiske Undersögelse), and Dr. Dahl becoming chief of the geologic survey of southern Norway.

OFFICIAL RELATIONS.

Although constituted by official authority, and nominally bureaus of the Home Department, the surveys can hardly be regarded as governmental institutions; they are properly private researches, subsidized by the Government.

The investigations are confined to the regions covered by the map sheets issued by the Geographic Survey, and these sheets are employed as bases for the delineation of the geology.

The collections are deposited in the cabinet of the University of Christiania.

The geologic maps are published by the Geographic Survey of Norway.

PLANS AND METHODS.

Small parties are annually equipped for the field during the short Norwegian summer, and provided with maps prepared by the Geographic Survey. The scales of these maps are 1-200,000, 1-100,000, and 1-50,000, the last being produced by photographic enlargement. Besides geologic maps, it is proposed to publish officially only such sections, profiles, and explanatory texts as are necessary for the comprehension of the maps.

PERSONNEL.

The director of each survey has two or three permanent assistants, and the summer expeditions are augmented by mining engineers and university students acting as temporary assistants.

COST.

The salaries of the corps appear not to be provided for by the official grants, which cover only traveling expenses and the publication of maps. The appropriation in 1883 was 10,030 kroner ($2,688).

PUBLICATIONS.

A limited number of the maps are exchanged with libraries and scientific institutions, and the remainder are placed on sale. Seventeen sheets in southern Norway have been issued, on a scale of 1-100,000. A map of Christiania, Hamar, and Christiansand, in ten sheets, on a scale of 1-400,000, has been published, with an explanatory pamphlet. A map of northern Norway, on a scale of 1-1,000,000, was published unofficially by Dahl, and a similar unofficial map of southern Norway has been published.

All results of the work of the survey not representable on maps are published unofficially in scientific journals.

RUSSIA.

The official geologic organization is styled "The Geologic Commission."

ORIGIN AND HISTORY.

Although geologic investigation received imperial sanction and indirect support in Russia as early as 1840 to 1844, when an examination of European Russia and the Ural Mountains was undertaken by Sir Roderick Murchison, Prof. Edouard de Verneuil, and Count Alexander von Keyserling, and although other extensive researches have been successfully carried out under the auspices of different Russian universities and societies, principally the Imperial Russian Geographic Society (Geographitcheskago Obwestva), it was not until after the commencement of the present decade that a systematic geologic survey was instituted by the Russian Government.

The Geologic Commission was created by a decree approved by the imperial council at Gatchina January 19, 1882.

OFFICIAL RELATIONS.

The commission constitutes a division of the Bureau of Mining Engineers of the Ministry of the Imperial Domain, to whom its reports are addressed. Plans of the commission and programmes for special work to be undertaken, the selection of candidates for employment, the assignment of special duties to members of the staff, the allotment of funds for specific purposes, the auditing of accounts, and regulations governing those sessions of the commission at which these matters are considered, are all subject to the approval of the Minister.

Provision is made for the establishment and maintenance of a museum for the preservation of the geologic and paleontologic collections of the commission.

The members of the commission meet in stated or special sessions, under the presidency of the director, for the consideration of scientific and administrative questions. By virtue of their professions, members of the mineralogic, geologic, and paleontologic sections of the Imperial Academy, and professors of mineralogy, geology, and paleontology of the Institute of Mines and the Imperial University of St. Petersburg, have admission to these sessions.

PLANS AND METHODS.

The objects of the commission, as enumerated in the imperial decree creating it, are: (1) to investigate systematically the geologic structure of Russia; (2) to prepare and publish descriptive and speculative treatises thereon; (3) to prepare and publish a geologic map of the Empire on a scale of 1–125,120; (4) to collect minerals and fossils and establish a systematic museum; and (5) to perform all other functions properly belonging to such an organization.

There are held both stated and called sessions of the members of the commission, to which the officers of the scientific institutions already specified have admission. At these sessions are considered; (1) general schemes for geologic investigation and specific programmes for work; (2) the institution of new survey and cartographic methods; (3) the publication of memoirs, maps, catalogues, &c.; (4) the acquisition of models and scientific appurtenances essential to the knowledge and practice of geologic art; (5) exchange of specimens and other property with similar institutions; (6) the presentation of publications to individuals and institutions; (7) the election of correspondents; (8) the selection of persons for employment; (9) the assignment of duties to employés, allotment of funds for their expenses, auditing of accounts, and discussion of reports; (10) the remuneration of subordinates; (11) the preservation of property; (12) the framing of regulations governing access to the museum; and (13) matters submitted by the minister of Imperial Domain. Deliberations upon matters contemplated under the thirteenth head are secret.

Proposals for the election of candidates to staff positions are also considered in secret session between November 15 and March 1 of each year. The proceedings of the commission are recorded.

Provision is made for the organization, equipment, and conduct of field-parties, and for the employment of untrained assistants supplementary to the scientific staff.

Members of the staff, other than the director, are prohibited from placing the results of their work before the public unofficially, and are required to preserve their various collections for the museum.

The general conduct of each field party is intrusted to a "commander of party," who is charged with the details of its organization, but appears to receive instructions as to movements from the scientific staff.

PERSONNEL.

The officers of the commission, their rank in the administrative personnel of the empire, and their salaries are shown in the accompanying table:

Office.	Class.	Number.	Salary.	
			Roubles.	
Director*	V	1	1,800	$1,161 00
Senior geologist	V	2	3,000	1,935 00
Do	V	2	1,500	967 50
Junior geologist	VI	3	1,500	967 50
Secretary†				
Conservator and archivist	IX	1	1,200	774 00

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*In addition to income from other offices.

†Salaried by bureau of mining engineers, but receives an annual allowance of 300 roubles ($193.50) from the commission.

Officers (except the director and secretary) who hold other offices, can only draw so much of the above amounts as will make their salaries equal to the rates stated.

The director is appointed by the sovereign from among the Mining Engineers of the Imperial Domain.

The senior and junior geologists are appointed by the Minister of Imperial Domain upon the nomination of the commission. They must be mining engineers noted for geologic work, and either graduates from one of the Russian universities, with a degree not less than master of geology, paleontology, or mineralogy, or Russian subjects graduated with equal honors by other universities.

The secretary of the commission is assigned by the Bureau of Mining Engineers. The secretary charged with the records of the sessions of the commission is designated by the director from among the junior geologists. The conservator of archives is appointed by the director, who is responsible for the property intrusted to his care. Unclassified assistants are employed by the director at his discretion.

"Commanders of party" do not belong to the scientific staff, but are assigned from the Bureau of Mining Engineers. Provision is made, however, for training individual commanders in the special work of collecting scientific material and presenting circumstantial reports on their work.

COST.

The sum annually appropriated for the Geologic Commission is 30,000 rubles ($19,350). Out of this sum 3,000 rubles ($1,935) are allotted for printing. The balance is devoted to the payment of salaries and incidental expenses, not including the pay of workmen, petty officers, and commanders of field parties; which expenses are paid by the Bureau of Mining Engineers. Since such employés are numerous, the sum annually appropriated represents only a small portion of the actual expenditure of the commission.

The revenue derived from the sale of publications, and unexpended balances are devoted to the advancement of independent geologic exploration or to the employment of independent specialists upon extraordinary occasions.

PUBLICATIONS.

The publications contemplated by the commission comprise, (1) "Isvestia," or Proceedings, in octavo, printed in the Russian language; (2) "Trudé," or Memoirs, in octavo, printed in either Russian, German, or French, at the option of the author; and (3) sheets of the geologic map contemplated in the constitution of the commission.

The Proceedings contain reports on the progress of the survey and the condition of the museum, abstracts of the proceedings of the sessions of the commission (including the discussions upon papers presented), and brief reports upon special investigations undertaken by the director and his subordinates. They are issued in numbers. Three volumes have thus far appeared.

The Memoirs comprise monographs on restricted areas, particular formations, or other clearly defined subjects. Three of these monographs have been published.

None of the sheets of the contemplated map have yet reached this country.

SWITZERLAND.

Geologic investigations are prosecuted by a commission for the collection of "material for a geologic map of Switzerland" (Beitrag zur geologischen Karte der Schweiz).

ORIGIN AND HISTORY.

The commission was instituted in 1859, when the Federal Council made a grant to the Society of Swiss Naturalists to aid in coloring geologically the Dufour map. As originally constituted the commission consisted of Studer (president), Merian, Escher, Desor, and Favre. Subsequently the plans of the commission became so far modified as to include the preparation of maps upon larger scales and the publication of memoirs relating to the geologic structure of Switzerland; but otherwise the functions and purposes of the commission have remained unchanged.

OFFICIAL RELATIONS.

The commission is directed by the Society of Naturalists, under the auspices and control of the federal department of the interior.

The members of the commission belong to the faculties of different educational institutions, and prosecute the work of the survey during intervals of leisure. The cost of the publication of the maps is borne by the Confederation; the Society of Naturalists publishes the memoirs; the Polytechnic School of Zurich purchases the collections for its cabinet at their actual value; and the commission is without any regularly established office. The survey thus depends for support upon different institutions: (1) Swiss universities, through their faculties; (2) the Academy of Sciences and the Polytechnic School; and (3) the Federal Council.

PLANS AND METHODS.

The different sheets of the Dufour map are intrusted to the members of the commission, who investigate the structure of the areas represented upon them in person and by means of the assistance of their pupils.

Office work is performed in the laboratories of the different members of the commission.

PERSONNEL.

The permanent staff is limited to the five members of the commission, whose work is generally gratuitous; and the temporary employés from the various educational institutions also appear to labor gratuitously; but the proceeds of the sale of collections revert to the collector. Traveling expenses are paid out of the annual grant from the Federal Council.

COST.

The annual appropriation, apparently designed to cover only field expenses and cost of publication, is fifteen thousand francs ($2,895). The commission, however, is credited with the sum received from the sale of maps, which sometimes reaches an amount equal to or even greater than the annual cost of the survey.

PUBLICATIONS.

The publications consist of map sheets and octavo papers (Lieferungen).

When completed the map will form twenty-five sheets, 23 by 29 inches. The scale is 1-100,000. Eighteen sheets have been issued. They are sold at a fair profit.

The "Lieferungen" comprise (1) explanations of one or more sheets of the map, (2) detailed descriptions of special districts (accompanied by maps on scales of 1-50,000 and 1-25,000), and (3) monographs, suitably illustrated, on paleontologic, stratigraphic, economic, and theoretic subjects.

Since the initiation of the series of 1862, twenty-eight "Lieferungen" have appeared. A few copies are exchanged by the Academy of Science; the remainder are sold at remunerative prices.

BELGIUM.

A "Geologic Commission" has control of the geologic service (Service de la Carte Géologique de la Belgique).

ORIGIN AND HISTORY.

The construction of a geologic map of Belgium under governmental authority was commenced in 1836. The work was conducted by André Dumont, and the map was published by the government in 1854.

During the progress of Dumont's investigation material was accumulated for several important geologic memoirs, which were published by the Royal Belgian Academy.

The present commission was established in 1877, as a section of the Royal Belgian Museum. The president is J. S. Stas.

OFFICIAL RELATIONS.

The Commission, with the Royal Museum, is in the Department of the Interior. It is composed of five members of the Royal Belgian Academy, who appear to have a general oversight of the affairs of the survey. The present director, M. Ed. Dupont, is also the director of the Royal Museum. The members of his corps are professors of geologic science in different educational institutions, university instructors, and students and other young men interested in the promotion of science. Thus the survey is intimately connected with the educational and scientific institutions of Belgium, and is the product of their co-operation.

PLANS AND METHODS.

The principal objects of the commission are: (1) the enlargement of Dumont's map; (2) the combination of the data incorporated in it, together with the results of independent observations, upon a general geologic map of the kingdom, on a scale of 1–20,000; and (3) the publication of such textual and illustrative matter as may be required to fully exhibit the geologic structure.

It is proposed to issue the map in seventy-two parts, each comprising eight sheets 23 by 31¼ inches. Each sheet is to be accompanied by explanatory text. The maps are pre-eminently economic; the nature of the soil is shown in detail, and the indurated rocks are represented only where actual outcrops occur.

It is the policy to assign each geologist to a separate formation, to which he is expected to confine his studies until its geologic relations and economic value have been fully determined.

PERSONNEL.

In addition to the five members of the commission (who are not charged with the actual work of the survey), the staff comprises a director, three "conservateurs," and eleven assistants. The members of the staff sustain relations with other institutions, from which their salaries are partly or wholly derived.

COST.

The appropriations for, and expenditures by, the survey do not appear to be made public; but since the cost of the survey is largely borne by the Royal Museum, and the salaries are divided among various other institutions, the appropriations must be small.

PUBLICATIONS.

The publications of the commission belong to three series, viz, sheets of the 1-20,000 map, folio Memoirs, and octavo Bulletins.

The Memoirs bear the title "Annales du Musée Royale d'Histoire Naturelle de Belgique." They consist of paleontologic, lithologic, stratigraphic, and zoölogic monographs. The stratigraphic series constitute the textual explanations issued with the separate sheets of the map.

The Bulletins contain minor treatises on miscellaneous matters.

The Memoirs and Bulletins appear to be issued at the expense of the Royal Museum, and the maps at the expense of the state. The various publications are sold at a profit.

NETHERLANDS.

An official geologic commission (Commissie voor de Geologishe Kaart van Nederland) appears to have been organized in the Netherlands a little after the middle of the century, when appreciation of the utility of geologic science first began to spread over Europe. Nothing is known of the commission save what can be gleaned from its single publication—a geologic map of the country, on a scale of 1–200,000, in twenty-seven small sheets, with explanatory text, published in 1856–'67.

CANADA.

Geologic and geographic explorations are conducted by the Geological Survey of Canada, at present in charge of Dr. Alfred R. C. Selwyn.

ORIGIN AND HISTORY.

Prior to the union of Upper and Lower Canada, several fruitless attempts were made to establish a geologic survey.

In 1841 a grant was made of £1,500, to be expended in making a geologic examination of the provinces. In 1842 two geologists were appointed, Mr. William E. Logan as principal, and Mr. Alexander Murray as assistant. Field work began in 1843.

In 1845 an act making provision for the formal establishment of a geologic survey of Canada was passed. By it there was appropriated the sum of £2,000 per annum for five years, to be expended in making a complete examination of the rocks, soils, and minerals of the provinces. In 1850 another act was passed renewing the provisions of that of the preceding quinquennial, and continuing the appropriation for five years more. Similar acts were subsequently passed from time to time, and under their provisions the survey was kept in progress until 1877.

In 1877 the title of the survey was changed to the "Geological and Natural History Survey of Canada," and the office was charged with the maintenance of the Provincial Museum. Otherwise its constitution and functions have remained unaltered from its origin to the present time.

OFFICIAL RELATIONS.

When first organized that survey was an independent governmental institution, under the immediate control of the governor, lieutenant-governor, or other persons administering the government of the province, acting by and with the advice of the Executive Council thereof.

PLANS AND METHODS.

In default of satisfactory topographic maps, the Survey has been compelled to undertake extensive geographic and topographic surveys for the construction of maps to be afterward employed in the delineation of geologic structure.

In general, geologic work is limited to rapid reconnoissances of different portions of the British dominion, some of which are altogether unexplored. Refined methods of investigation have been adopted only in limited areas about the Great Lakes and along the Saint Lawrence river.

PERSONNEL.

In 1881 the official staff comprised: 1 chief officer (the director), 4 first-class officers (assistant directors), 8 senior second-class officers, 5 junior second-class officers, and 2 third-class assistants.

There are two members of the survey who have been retired under the superannuation provisions of the civil service act.

The salary of the director is $4,000, and his four assistants receive each $1,850 a year. Other geologists are paid $1,800 per annum, while still more subordinate officers are paid from $800 to $1,600.

The director receives his appointment from the Governor-General. Appointments to subordinate positions are made by the Governor-General in Council, upon the nomination of the director. Temporary appointments, which can extend only over a period of three months, are made by the director.

Promotion is generally determined by special proficiency and seniority; but the chief officers have hitherto been imported.

COST.

The following appropriations have been made for the support of the Geological Survey. They do not include the cost of publication:

Year.	Amount.		Year.	Amount.	
1841	£1, 500	$7, 297 50	1852	£2, 000	$9, 730 00
1842–'44 not ascertained			1853	2, 000	9, 730 00
1845	2, 000	9, 730 00	1854	2, 000	9, 730 00
1846	2, 000	9, 730 00	1855–'72 not ascertained		
1847	2, 000	9, 730 00	1873		30, 000 00
1848	2, 000	9, 730 00	1874–'80 not ascertained		
1849	2, 000	9, 730 00	1881		45, 000 00
1850	2, 000	9, 730 00	1882		45, 000 00
1851	2, 000	9, 730 00	1883		60, 000 00

PUBLICATIONS.

The chief publications of the survey belong to a single series, viz, Reports of Progress. The issue of this series began in 1845 and yet continues. During the earlier years the reports were only thin pamphlets, but with the progress of the survey their size has increased to volumes of from 500 to 800 pages. The reports are illustrated by geographic and geologic maps, on scales best adapted to the delineation of the structure of the regions described, and by geologic sections, profiles, views, &c. About thirty of these reports have appeared, including the voluminous report published in 1863, which included the more important facts published in those of preceding years. They are accompanied by an atlas and numerous maps in portfolios. They are issued in both French and English.

Many special reports have been published, including catalogues of the economic minerals of Canada, and reports on various gold regions.

Under the head of "Figures and Descriptions of Canadian Organic Remains," four volumes (or decades) of octavo monographs have been issued. A more elaborate paleontologic monograph, by E. Billings, on paleozoic fossils, was published in 1865. In 1871 and in 1873 two volumes on fossil plants, by J. W. Dawson, were issued, followed in 1876 and 1879 by two parts of a volume on Mesozoic fossils, by J. F. Whiteaves.

Besides the maps in atlas form and the portfolios already mentioned as accompanying the Report of Progress, various maps have been separately published. Among these are (1) Sir William E. Logan's map of Canada and contiguous portions of the United States, scale 25 miles to the inch, which was issued in eight sheets; (2) a map of Springhill coalfield, &c., in Nova Scotia; (3) three miscellaneous maps; (4) four sheets of a prospective atlas of Canada, on a scale of 4 miles to 1 inch (= 1:253,450), measuring 24 by 18 inches; and (5) a geologic map of the Dominion of Canada, scale 40 miles to the inch, 31 by 84 inches, published in 1884 and accompanied by an explanatory memoir.

A limited number of publications are distributed gratuitously, and the remainder are placed on sale in Ottawa and Montreal.

It is worthy of remark that Canada many years ago adopted the rectangular system of parceling surveys which originated in the United States; but they have been executed by refined methods, so that the land office surveys will ultimately constitute the basis of a topographic map and of cadastral maps, and many millions of dollars will thereby be saved. This superior work has been accomplished at less expense than corresponding work in the United States. The plan originally adopted in this country contemplated good work, and had it been carried on as designed a topographic map could now be made over the same country with a saving of many millions of dollars, and ultimately cadastral surveys could have been made with a saving of scores of millions of dollars. But bad administrative methods prevailed by the growth of a non-competitive contract system, and bad operative methods obtained in the use of instruments of little precision, and the work has never been properly inspected or tested, so that altogether the surveys have been very badly executed at a large expense even for good work—and these vicious methods are still retained.

INDEX.

Page.
Academy of Science recommendation for a department of science 26
Act organizing the survey 17–18
Add to or take from Coast Survey work 32
Administration, geographical surveys, Austro-Hungary 401
    Belgium 411
    Denmark 411–412
    Germany 399
    Great Britain 395
    India 397–398
    Italy 405
    Norway 407–408
    Russia 408–409
    Spain 402–403
    Sweden 406
    Switzerland 410
  of geographic surveys in general 380–382
  questions of 412
Aid derived from railroad surveys 44–45
  State surveys 44–46
Alabama surveyed under the public land system 9–10
Alaska included in the linguistic classification of the Indian tribes 193
Alsace-Lorraine, geological survey 431
Ambiguity of early bills for surveys avoided by substitution of "United States" for "national domain," in later bills 3
Appropriation for Hayden survey of the Territories 47
Appropriations for ethnologic distinct from those for geologic work 191
  King survey of the fortieth parallel 47
  Powell survey 47
  United States Geological Survey by years 47
  Wheeler survey 47
Archæologic and linguistic researches, nowhere completed 194–195
  researches resulted in change of boundary lines 193–194
Arcs of meridians and parallels, measurement 413
Area surveyed 47
Arkansas, work in 10
Atlas to show cessions of land by Indian tribes, and distribution of Indians when white man arrived 191
Austria, geological surveys 432–434
Austro-Hungary, geographic survey 401–402
  geological surveys 432–434
Authority exercised by the Secretary of the Interior regarding the map-making 7
  for extending surveys into old States 2–3
    geological survey in Eastern States 2, 3, 16–17
    work for a State and its incorporation into national work 5

Page

- Avoidance of duplication of work, 3, 4, 22, 23, 32
- Bancroft classifies native tribes geographically, 195
- Basis of Gun Foundry Board, 32
- Bavaria, geological survey, 430–431
- Belgium, geographical surveys, 411
  - geological survey, 447–449
  - topographical map system, 417
- Berlin Conference, 1864, 412, 413
- Best method of constructing cadastral maps, 387
  - military maps, 388
  - topographic maps, 383
- Bloomington, Ill., loss of land survey lines and remedy, 15
- Bohemia, geological survey, 434
- Borden triangulation, the Massachusetts State work, 4, 9
- Bridges not indicated on maps, 42
- British, "committee of exclusion" for mapping, 6
  - ordnance maps published for sale, 46
  - surveys, 39–40
- Bureaus to be placed co-ordinately under one head, 28–30
- Cadastral maps as related to the work of the Coast Survey, 184
  - best method of constructing, 387
  - surveys, defined, 379
    - Denmark, 412
    - France, 393–395
    - how made, 380–381
    - important in America, 164
    - India, 399
    - purpose of, 162
    - Russia, 410
    - Spain, 404
- California, geological survey, 9
- Canada, geological survey, 449
- Change from "national domain" to "United States," in scope of survey, 3
- Character and value of Coast Survey maps, 41
- Clarence King deemed early acts for survey ambiguous, 2
- Classification of Indians by linguistic affinities, 192
  - languages includes all North America, 193
  - scientific work prosecuted by the Government, 23–25, 28–29
- Climatic observations, 173–175
- Coast and geodetic survey in States, 33–34
  - work, 3, 4
    - not duplicated by Geological Survey, 3
    - to be enlarged in scope, 28–29
  - Survey, a Government work, 187
    - coast charts, 166
    - lines not used to determine property lines, 201
- Colorado maps show depressions and elevations in Rocky Mountains, 201
  - surveyed by Hayden, 201
- Comparative cost of map-making by Coast and Geodetic and Geological Surveys, 206–208
- Compensation of employés, 46–48
- Completed portions of United States map, 41
- Completion of map sections, 41
- Concurrence of opinion among scientific men in favor of Government doing the present work, 188
- Consolidation to prevent duplication of work, 22, 23
- Construction of cadastral maps and their relation to topography, 184
- Constructive engineers, Spain, 404
- Co-operation with State geologists, 43
- Co-ordination of scientific organizations needful, 25
- Corrections not made by reason of geodetic survey in territory already surveyed, 209
- Cost, geographic surveys, Great Britain, 397
  - India, 399
  - Norway, 408
  - Sweden, 407
  - geological survey, Austria, 433
    - Bavaria, 430
    - Belgium, 448

Page.
Cost, geological survey, Canada ... 450
    France ... 421
    Great Britain ... 424
    India ... 426
    Italy ... 440
    Norway ... 443
    Russia ... 445
    Sweden ... 442
    Switzerland ... 447
  to a State of maps derived from United States geological maps ... 42
    complete the survey ... 43
Courts maintain difference between land surveys and State surveys under acts of Congress ... 14
Critical remark on geodetic and topographic surveys ... 388–389
Cultural topography mapped ... 6, 43
Date of authority for geodetic work ... 2
    to begin United States Geological Survey at the east ... 3
  geodetic work ... 2
Degree of accuracy reached by coast and geodetic and geological survey compared ... 205–206
Denmark, geographic surveys ... 411–412
  topographical map system ... 417
Department of Science, as recommended by Academy of Sciences ... 26
    the Interior suitable for co-ordinated scientific bureaus ... 31
Details of United States local survey maps ... 7
Dictionary of altitudes ... 44
Difference between topographic, geologic, and geographical maps ... 11–12
  in preparation for large maps and that for small maps ... 6
Director Powell's former characterization of Land Office surveys ... 10
Discrimination in relation to scientific work done under Government departments ... 186–187
Disposition suggested of the Hydrographic Office ... 30
Distinction between topographic, geological, and geographical maps ... 11–12
"Dufour map," Switzerland ... 410
Economic geology, how far followed ... 35
  importance of geodetic maps ... 40, 41
      surveys ... 40, 41, 389
Economy of combining topographic and geologic surveys ... 170
  expense with regard to personnel or material transported ... 193
  scientific modes in original surveys ... 16
Elevation of gulf stream determined by geodetic survey ... 37–38
Elevations, precise determination ... 414
Engineering surveys ... 379
English published ordnance maps valuable to a hostile force ... 46
Engraving maps in foreign countries ... 386
Enlargement of United States map by State of Massachusetts practicable ... 6
Errors of topographic maps perpetuated in geologic maps ... 8
Essentials for United States geological maps ... 6, 7
Ethnologic and geologic accounts kept separate ... 191
  reports made ... 194, 196
    published annually and distributed through Congress ... 196
  work done by those prosecuting work of the Geological Survey ... 191
    partly by the geologic force, partly by separate experts ... 191
    under appropriations and directions through the Smithsonian Institution ... 191
European maps on theory of military use ... 6
  surveys ... 40
Expenses of ethnologic researches, how paid ... 191
Experimental test of Land Office maps ... 10
Extension of work to economic details ... 35
Extent of system of triangulation in the United States ... 37
  work in Territories ... 35
  to which geologic formations have been plotted on topographic maps ... 185
Facts determined by geological survey ... 36, 37
  represented on geological map ... 42, 45
  to be represented on topographic maps ... 383
Field temporary employés ... 49
Final accuracy in earlier parts of maps occupying years in completion ... 43
Five hundred include all languages in North America ... 195

Page.
Five hundred languages include dialects 195
Force employed in the Geological Survey 43, 48–49
Form of appropriation for ethnology 191
    geologic maps for public use 41–42
    maps 42
France, geological survey 420–421
    topographic map system of 414
French Academy of Science surveys 390, 391
General plans, geographic survey, Denmark 412
    surveys, Austro-Hungary 402
        Germany 400
        Great Britain 396
        India 398
        Italy 405–406
        Norway 408
        Portugal 405
        Russia 409
        Spain 403–404
        Sweden 406–407
General staff German Government organization 399, 400
    systems of maps needed 383
Geodesy carried on by each European nation 166
    France 390–392
    questions of, at Berlin Conference, 1864 413
Geodetic Institute, Germany 399
    maps more enduring than geologic maps 40
    Survey, a Government work 187
        and Geological Survey compared in determination of points 167
        defined 379
        India 398
        nowhere complete 39
        of economic importance 40, 41, 389
    surveys, important in America 164
        purpose of 162
    work by Coast and Geodetic Survey would cost more than it would save the Geological Survey 208
        in British Isles, how extensive 40
            United States 166
        of other nations, how extensive 39, 40
        of the Geological Survey 1
        Russia 409
        to be done by State Governments, or by the General Government 165
Geographic Institute of Spain, maps 404
    surveys as conducted by various European Governments 390–417
Geologic commission, Belgium 447
        Russia 443
    map (*see also* Geological Surveys of foreign countries) 7, 8
    surveys of foreign countries 418–451
        to discover economic values 162
Geological Survey, a Government work 187
        comprehends topography and geography 16
        more efficient by controlling geologic and topographic surveys 171
        work benefited by work of Coast Survey 208
        work complete where topographic maps are complete 185
Germany, geographic surveys 399–401
    geological survey 427–431
    topographical map system 415
Government organizations to develop local effort 177
Great Britain, geographic surveys 395–397
    geological survey 421–425
    topographic map system 415
Hungary, geological survey 434
Hydrographic Bureau of the Navy 29
    work of Coast Survey transferable to the Navy 30
Important facts discovered under the survey 36–37
India, geographic surveys 397–399
    geological survey 425–427

Page.
India, topographical map system 415
Indiana, triangulation for the Lake survey 5
International Geodetic Association of Europe 412-414
    Geological Congress 165, 419
    Meridian convention an outgrowth of International Geodetic Association 166
Irrigating works, India 388
Italy, geographic surveys 405-406
    geological survey 438-440
    topographical map system 416
Joint work of Massachusetts and the United States Geological Survey 5, 6
    work of New Jersey and the United States Geological Survey 5
Joslyn, M. L., transmits memorandum by Director of Geological Survey regarding transfer to Coast Survey of work in charge of Geological Survey .. 162
Kansas, work in 10
King survey designated 17
Lake surveys by the Army engineers 5
Land and other surveys independent of each other 13
    Office maps, how far available preliminaries to geologic maps 10
        serve for topographic maps 9, 10, 11
Language not including "patois" 195
    of appropriation bills 16, 17, 18, 19
Law for extending the survey 34
Legislation for survey theoretically under constitutional provision for regulating commerce between the States 33
Line between Government work and work of private investigators 187
Location of previous scientific surveys 2
Maine geological surveys 8, 9
Manner and amount of geodetic work 1
Map-sheet size, in various countries 385-386
    size in United States Geological Survey topography 386
Map should include 6
Maps, cadastral, best method of construction 387
    of the Geographic Institute, Spain 404
    to indicate work of various surveys 1, 2, 3, 4, 5
Massachusetts growing up to timber 45
    State surveys 4, 5, 8, 9
Measurement of the intensity of gravity 414
Measurements of arcs of meridians and parallels 413
Meridians explained 12-15
    of the Land Office arbitrary 12, 13, 15
Method of representing topographic facts 384
    adopted for cadastral and geodetic surveys in various countries 378
    in other countries for geological surveys 378
        topographic surveys 378
Methods of reproduction of standard topographic maps in various countries. 386
    of survey in Coast and Geodetic and Geological Surveys compared . 202-205
Michigan State geological survey 9
    triangulation for Lake survey 5
Military Geographical Institute, Austro-Hungary 401
    maps, best method of constructing 388
Missouri, work in 10
Mode of printing maps 43
Modification of language in appropriation bills 17, 19
Museum of practical geology, Great Britain 422
National Observatory might consolidate with Coast and Geodetic Survey 29
    Academy of Sciences, recommendation for continuation of Geological Survey 172
    Observatory, relations to Geological Survey 23, 29, 176
Nations represented in International Geodetic Association 165
Native tribes of Pacific coast included in linguistic classification 193
Naval Advisory Board 31, 32
Netherlands, geological survey 449
    topographical map system 417
New York State survey 4
Niobrara meridian 13, 14
No monopoly in research 187
North Carolina, geological survey 9
Norway, geographic surveys 407-408

Page.
Norway, geological survey ... 442
  topographical map system ... 416
Number of sheets in United States map ... 42
  languages in North America ... 195
Objections to National Academy plan of consolidation of scientific bureaus ... 26-27
Office employés of the Geological Survey ... 48
Offices that might be combined co-ordinately under one head ... 30
Official relations, geological survey, Austria ... 432
  Bavaria ... 430
  Belgium ... 448
  Canada ... 449
  France ... 420
  Great Britain ... 422
  India ... 425
  Italy ... 438
  Norway ... 443
  Portugal ... 437
  Prussia ... 428
  Russia ... 444
  Saxony ... 431
  Spain ... 436
  Sweden ... 441
  Switzerland ... 446
"Ordnance Survey," Great Britain ... 395
Organization of the Smithsonian Institution ... 27-28
Origin and history, geological survey, Austria ... 432
  Bavaria ... 430
  Belgium ... 447-448
  Canada ... 449
  France ... 420
  Great Britain ... 421 422
  India ... 425
  Italy ... 438
  Norway ... 442
  Portugal ... 437
  Russia ... 443-444
  Spain ... 434-436
  Sweden ... 441
  Switzerland ... 446
Other German states, geological surveys ... 431
Parceling surveys, purpose of ... 163
Pennsylvania geological surveys ... 8, 9
Personnel, geographic surveys, India ... 398
  geological survey, Austria ... 433
    Belgium ... 448
    Canada ... 450
    France ... 421
    Great Britain ... 423
    India ... 426
    Italy ... 439
    Norway ... 443
    Portugal ... 438
    Prussia ... 429
    Russia ... 445
    Saxony ... 431
    Spain ... 436
    Sweden ... 442
    Switzerland ... 447
  ordnance survey, Great Britain, 1882 and 1883 ... 396
Plan presented to committee of Academy of Sciences ... 23-30
  suggested by Major Powell to committee of Academy of Sciences for operation of scientific work ... 22, 23
Plans and methods, geological survey, Austria ... 432
  Bavaria ... 430
  Belgium ... 448
  Canada ... 449-450
  France ... 421
  Great Britain ... 423
  India ... 425

Page
Plans and methods, geological survey, Italy 439
Norway 443
Portugal 437–438
Prussia 428–429
Russia 444
Saxony 431
Spain 436
Sweden 441
Switzerland 447
Portugal, geographic surveys 405
geological survey 437–438
topographical map system 416
Powell survey designated 17
Power of Congress to carry geological surveys into the States 33
Practical value of geodetic work 35–36
Precedent for United States survey in States 34
Precise determinations of elevations 414
Preliminary remarks to geological surveys of foreign countries 418–420
Present scientific investigations of the Government how far undertaken by individuals 187
work in ethnology 191
Previous discussion in Congress 2, 3
Principles of official organization and superior control in Government scientific work 24–26
Progress of ethnologic work in the East 193
Prussia, geological survey 427–430
Public land surveys not related to scientific survey 12, 13, 14, 15
Publications, ethnology 196
geological survey, Austria 433–434
Bavaria 430
Belgium 448
Canada 450–451
Great Britain 424–425
Hungary 434
India 421, 426–427
Italy 440
Norway 443
Portugal 438
Prussia 429–430
Russia 446
Saxony 431
Spain 436–437
Sweden 442
Switzerland 447
United States 35, 44
rapidly exhausted 196
Purpose and propriety of furnishing established points for States 172–173
of change from "national domain" to "United States" in bills 3
of geodetic survey 35–36
Purposes to be subserved by maps of Coast and Geodetic Survey and Geological Survey, and their difference 197–202
Questions of administration at Berlin Conference, 1864 412
astronomy and physics, Berlin Conference, 1864 412
geodesy at Berlin Conference, 1864 413
Railroad engineers found correct 45
Relation of archæologic researches to boundary lines 193–194
certain employés to colleges 196
employés of the Geological Survey to educational institutions 196
geodetic work of Coast Survey to that of Geological Survey 208–209
geologic to geodetic work 38
geologists, paleontologists, and general assistants of the Geological Survey to the survey and to other employments 188–190
Relations of Cabinet officers to scientific work 30, 31
the Geological Survey to the Fish Commission 28
Geological Survey to Massachusetts 22
Geological Survey to the National Observatory 23, 29, 176
Geological Survey to the National Museum 28
national to local surveys 43
work of the Geological Survey to the other surveys 3, 4, 5

Page.

Relation of topographic, geodetic, and cadastral surveys ... 382
    Land Office surveys and scientific surveys ... 13–14
    Naval Advisory Board and others to Cabinet officers ... 31–32
    Massachusetts and the United States in survey of Massachusetts. 22
    United States and State surveys ... 34–35
    scientific men to officials ... 178
  between geologic and ethnologic work ... 191–193
      other bureaus and Geological Survey ... 173–180
      Signal Service and Geological Survey ... 173–175
Reports published and exhausted through Congress annually ... 196
Russia, geographic surveys ... 408–410
  geological survey ... 443–446
  topographical map system ... 416
Saxony, geological survey ... 431
Scale for topographic maps ... 384–385
  of maps ... 5, 6, 385, 386, 387
    (See also under each foreign survey.)
  of maps of Geological Survey for public use ... 41–42
Scales of cadastral maps of foreign states ... 387
  standard topographic maps of foreign states ... 385
Scientific employés United States Geological Survey ... 48
  research by the British Government ... 30
      German Government ... 30
      Russian Government ... 30
    how far a government function ... 29–30
  duties of the geologists, paleontologists, and general assistants of the Geological Survey ... 188
  men concur in favor of present work by the Government ... 188
Shaler, N. S., a member of the Massachusetts commission ... 5
Signal Service interested in work of Geological Survey ... 174
    origin and growth ... 173
    records utilized by Geological Survey ... 175
    to be assigned according to decision to retain it as military or make it a civil work ... 29
    work a Government work ... 187
Sixty stocks of languages include ... 195
Size of map sheets in United States Geological Survey topography ... 386
      various countries ... 385–386
Spain, geographic surveys ... 402–404
  geological survey ... 434–437
  topographical map system ... 416
State of advancement of archæologic and linguistic researches ... 194
  surveys utilized ... 4
States could authorize the United States to do the work under their power of eminent domain ... 33
  organizing to complement the United States work ... 34–35
  that form the German Empire ... 400
Summary of employés of the Geological Survey ... 49
Sundry civil bill of last year, authority for extending surveys into old States. 2
Surveys. (See cadastral, geodetic, geographical, geologic, geological, topographic, and names of European countries.)
  anterior to present ... 2
  in India ... 40
    old States, under provision for geological map ... 2, 3
  to be prosecuted by States and surveys to be prosecuted by General Government ... 381–382
Sweden, geographic surveys ... 406–407
  geological survey ... 441–442
  topographical map system ... 416
Switzerland, geographic surveys ... 410
  geological survey ... 446–447
  topographical map system ... 417
System of governmental scientific institutions grown out of experienced wants. 179
Table showing the topographic map system of various foreign countries ... 414–417
Time and cost of geodetic work complete ... 35
  required to complete the survey and maps ... 43
  to complete archæologic and linguistic investigations ... 195
Topographer, the, how utilized in geologic surveys ... 170
Topographers, draughtsmen ... 170